ORNL-4101
C.2

ORNL-4101
UC-48 – Biology and Medicine

DOSE-ESTIMATION STUDIES RELATED TO PROPOSED CONSTRUCTION OF AN ATLANTIC-PACIFIC INTEROCEANIC CANAL WITH NUCLEAR EXPLOSIVES: PHASE I

K. E. Cowser
S. V. Kaye
P. S. Rohwer
W. S. Snyder
E. G. Struxness

OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

Printed in the United States of America. Available from Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Virginia 22151
Price: Printed Copy $3.00; Microfiche $0.65

ORNL-4101

Contract No. W-7405-eng-26

HEALTH PHYSICS DIVISION

DOSE-ESTIMATION STUDIES RELATED TO PROPOSED CONSTRUCTION OF AN ATLANTIC-PACIFIC INTEROCEANIC CANAL WITH NUCLEAR EXPLOSIVES: PHASE I

K.E.Cowser, S.V.Kaye, P.S.Rohwer, W.S.Snyder, and E.G.Struxness

MARCH 1967

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

FOREWORD

In Public Law 88-609, the Congress of the United States authorized an investigation and study of sites for construction of a sea-level canal connecting the Atlantic and Pacific Oceans. A five-member Commission appointed by the President must determine the feasibility, the most suitable site, and the best means of constructing such a canal, whether by conventional or nuclear excavation. The Commission has selected a number of Departments within the United States Government to conduct supporting studies, and they in turn have called upon other government and private agencies for assistance.

Battelle Memorial Institute (BMI), as a principal AEC Contractor, is responsible for the management of studies to determine the radiological safety of using nuclear explosives to excavate the proposed canal through southern Panama or northern Colombia. BMI has awarded subcontracts for studies in ecology (including human, agricultural, terrestrial, marine, and freshwater ecology), in physiochemical oceanography and hydrology, and in dose estimation. The Health Physics Division of the Oak Ridge National Laboratory has the subcontract (Purchase Contract No. S6230) to make estimates of dose to man and to compare these estimates with appropriate radiological safety standards. All information reported in this document was obtained under the auspices of the AEC Nevada Operations Office for the Atlantic-Pacific Interoceanic Canal Commission.

ACKNOWLEDGEMENTS

The authors wish to acknowledge that all computer work was done by P. M. Kannan and D. Winkler of the Mathematics Division, ORNL.

Appreciation is expressed to Norma Brashier, Beverly S. Varnadore, and Mary W. Buchanan who typed the manuscripts and assisted with proofreading.

CONTENTS

CONTENTS, continued

CONTENTS, continued

CONTENTS, continued

LIST OF FIGURES

LIST OF TABLES

DOSE-ESTIMATION STUDIES RELATED TO PROPOSED CONSTRUCTION OF AN ATLANTIC-PACIFIC INTEROCEANIC CANAL WITH NUCLEAR EXPLOSIVES: PHASE I

K.E.Cowser, S.V.Kaye, P.S.Rohwer, W.S.Snyder, and E.G.Struxness

ABSTRACT

This report presents information obtained by ORNL in Phase I of dose-estimation studies to evaluate the radiological-safety feasibility of excavating an Atlantic-Pacific interoceanic canal with nuclear explosives. The information includes (1) methods for estimating external and internal dose equivalents, for quantifying the transfer of radionuclides through critical exposure pathways, and for identifying the radionuclides likely to be critical; (2) criteria for evaluating the radiological safety of the operation; and (3) lists of radionuclides arranged according to the dose commitment that results from exposure to a unit quantity of each radionuclide.

Equations to estimate external and internal radiation dose commitments were developed which account for production, venting, and movement of radionuclides in environmental exposure pathways. A compartment model for representing movement of radionuclides in the tropical environment was designed with coupled compartments having income and loss fluxes controlling the inventory of radionuclides which may have inputs to man. The specific-activity concept for estimating the allowable radionuclide concentrations in the environment was evaluated in a way that reveals its limitations, considering the time-dependent relative importance of radioactive half-life, biological half-time, and biological growth.

Criteria for evaluating radiological safety were developed from the recommendations of recognized authorities which might reasonably apply in an operation of this magnitude, taking account of the principle of balancing the possible benefits against the potential risks.

1.0 INTRODUCTION

The Phase I dose-estimation studies to be performed under the ORNL contract were delineated by BMI as follows:

Task 1. Identify the radionuclides that may contribute the largest dose equivalents[a] to man from both external and internal sources.

Task 2. Propose methods for estimating the potential external and internal doses.

Task 3. Identify, interpret, and describe the radiation protection guidelines applicable to the radiological-safety feasibility study.

Task 1 is essentially a ranking of radionuclides based on their potential contributions to external and internal doses for specified conditions of exposure. Imperative to such a ranking is information on the production, venting, and environmental pathways of radionuclides. In Task 2, a general procedure is to be developed for assessing radionuclide movement and retention in the environment, permitting estimates of potential radiation exposure of indigenous populations. Specifications of data required from the on-site studies of other subcontractors in Phase II is a part of this task, with particular attention given to application of the specific activity concept as a method of evaluating the hazard to man from radionuclides entering the food chain. Task 3 requires identification of problems peculiar to the canal situation, and study of guidelines,

---

[a]Dose-Equivalent (rem) = Absorbed Dose (rad) x modifying factors. For the sake of convenience, "dose" will be used hereafter instead of "dose equivalent".

published by radiation protection authorities, that are likely to be applied in the final evaluation of population exposures.

Phase II studies have already been planned by BMI, and they include the estimation of doses to individuals or groups in the Central American populations, using methods developed in Phase I and basing the estimates on on-site data collections and field experiments.

2.0 GENERALIZED MODELS FOR DOSE ESTIMATION

2.1 External Dose

In the case of external exposure from radionuclide i at location k, an expression $Y_i f_{ij} P_{ijk}(t)$ is a measure of the level of contamination (μCi/g or μCi/cm^2, dependent upon the pathway of exposure j) present at post-detonation time t. In this expression, Y_i is the yield (μCi) of radionuclide i, f_{ij} is the fraction of Y_i entering or available to pathway j, and $P_{ijk}(t)$ is the concentration (μCi/g per μCi released or μCi/cm^2 per μCi released) of radionuclide i present in pathway j for location k at time t per unit activity of radionuclide i initially available to pathway j. The dose rate via pathway j at time t to an individual of age γ (years) at location k would be $Y_i f_{ij} P_{ijk}(t) C_{ij}(\gamma)$ in units of rems/day. The dose rate term $C_{ij}(\gamma)$ is the dose rate to the reference tissue of an individual of age γ exposed to a unit concentration of radionuclide i in the mode of exposure appropriate for pathway j, and thus includes all necessary factors which account for the habits and characteristics of the individual, including occupancy factors. The modes of exposure considered are irradiation from a contaminated surface, submersion in contaminated water, and submersion in contaminated air. The total dose, $D_{ijk}^{\text{ext.}}[t_1, t_2, \gamma(t_1)]$, due to radionuclide i in pathway j at location k, accumulated from time t_1 to time t_2 for an individual of age $\gamma(t_1)$ at the beginning of the exposure period is given by

$$D_{ijk}^{\text{ext.}}[t_1, t_2, \gamma(t_1)] = Y_i f_{ij} \int_{t_1}^{t_2} P_{ijk}(t) C_{ij}[\gamma(t)] dt \quad \text{(rem)}. \qquad (2.1)$$

2.2 Internal Dose

The level of contamination $[Y_i f_{ij} P_{ijk}(t)]$ at post-detonation time t is as defined in Sect. (2.1), although the concentrations considered here would be those in materials which may be ingested or inhaled. These are the only modes of exposure considered here. The expression $C_{ij}[\gamma(t),\ t_2-t]$ denotes the dose commitment in the t_2-t days following a one-day exposure of an individual then of age $\gamma(t)$ in an environment containing a unit concentration of radionuclide i in the mode appropriate for pathway j. This expression is considered to include all factors which account for habits and characteristics of the individual, including occupancy factors. The total dose accumulated to time t_2 for an exposure beginning at time t_1 is given then by

$$D_{ijk}^{\text{int.}}[t_1,t_2,\gamma(t_1)] \;=\; Y_i f_{ij}\int_{t_1}^{t_2} P_{ijk}(t)C_{ij}[\gamma(t),t_2-t]dt \quad \text{(rem)} \qquad (2.2)$$

The dose commitment $C_{ij}[\gamma(t),t_2-t]$ is considered as a function of time because the time interval t_1 to t_2 may extend over years, and the dose commitment may vary as a function of age. This is particularly important for assessing exposure of fetuses and infants.

2.3 Total Dose

Equations (2.1) and (2.2) will be used to calculate doses for all significant radionuclides and modes of exposure, and these doses will be

summed to obtain an estimate of the total dose incurred by an individual in a specified environment during the time interval t_1 to t_2. Total dose estimates must include dose contributions from vented and non-vented radionuclides since both are potential sources for external and internal exposure. The models presented are applicable in all cases.

3.0 EXTERNAL DOSE ESTIMATIONS

3.1 Dose Models

The following subsections include the models used in calculating external dose and the assumptions made in applying the models.

3.1.1 Submersion Exposure to Beta Radiation[3.1]

When water is the contaminated medium,

$$D_i = 25.6\ Q_i E_i\ \text{(rem/day)}\ ; \tag{3.1}$$

and where air is the contaminated medium,

$$D_i = 29.2\ Q_i E_i\ \text{(rem/day)}\ ; \tag{3.2}$$

where

D_i = dose rate due to ith radionuclide (rem/day),

Q_i = concentration of ith radionuclide (μCi/g), and

E_i = effective absorbed energy of a beta disintegration (Mev).

3.1.2 Submersion Exposure to Gamma Radiation[3.1]

When water is the contaminated medium,

$$D_i = 51.2\ Q_i E_m\ \text{(rem/day)}\ ; \tag{3.3}$$

and when air is the contaminated medium,

$$D_i = 29.2\ Q_i E_m\ \text{(rem/day)}\ ; \tag{3.4}$$

where D_i and Q_i are as defined above, and E_m is the energy of gamma radiation (Mev).

Submersion dose rates in contaminated water [Eqs. (3.1) and (3.3)] were calculated by assuming that the body is in the center of a sphere and receives equal quantities of radiation from all directions. Other assumptions included: (1) the radius of the contaminated water is large in comparison to the range of beta particles and to the half thickness of the water for gamma rays, (2) an effective absorbed energy that is equal to the average energy of the beta particle, and (3) a short penetration distance for the beta particle in the body, thus limiting beta radiation to body surface exposure. Similar assumptions are made with air as the contaminated medium [Eqs. (3.2) and (3.4)]. A small correction is made by considering the range of beta particles in air and the density of air which is reflected in the constant term of Eqs. (3.1) and (3.2). Exposure to man in air is likely to result while standing on the ground surface; the body is receiving gamma radiation from 2π steradians and the dose rate calculated by Eq. (3.4) is about 1/2 of that calculated by Eq. (3.3). The total submersion dose rate for a particular radionuclide is the sum of Eqs. (3.1) and (3.3), or (3.2) and (3.4), if both beta and gamma transitions occur during decay. A requisite for these calculations is the concentration of the radionuclides per unit mass of the medium. However, the time required for a contaminated cloud to pass any downwind point may be short. Thus, it would be possible to calculate total dose from submersion in contaminated air when the air concentrations are expressed in Ci-sec/m^3.

3.1.3 Beta Radiation from a Contaminated Surface.[3.2]

$$D_i(a) = 1.070\ \nu\ \bar{E}\alpha N \left\{ C \left[\left(1 + \ln\frac{C}{\nu a}\right) - e^{1 - \frac{\nu a}{C}} \right] + e^{1 - \nu a} \right\} \text{ (rem/hr)}, \quad (3.5)$$

$$\left[(1 + \ln\frac{C}{\nu a}) - e^{1 - \frac{\nu a}{C}} \right] \equiv 0 \quad \text{when } \nu a \geq C, \tag{3.6}$$

$$\nu = \frac{18.6}{(E_o - 0.036)^{1.37}} \left(2 - \frac{\overline{E}}{E^*}\right) , \tag{3.7}$$

$$\alpha = \left[3C^2 - (C^2 - 1)e \right]^{-1} , \tag{3.8}$$

$$C = \begin{cases} 3 & E_o < 0.17 \\ 2 & 0.17 \leq E_o < 0.5 \\ 1.5 & 0.5 \leq E_o < 1.5 \\ 1 & 1.5 \leq E_o \end{cases} , \tag{3.9}$$

where

$D_i(a)$ = dose rate(rem/hr) due to ith radionuclide,

a = distance above ground surface (g/cm^2),

ν = absorption coefficient (cm^2/g),

$\overline{E}$ = average beta-ray energy (Mev),

E_o = maximum beta-ray energy (Mev),

E^* = average beta-ray energy (Mev) for a forbidden spectrum,

$\overline{E}/\overline{E}^*$ = 1 for allowed spectra, and

N = level of ground contamination ($\mu Ci/cm^2$) .

Equations (3.5) through (3.9) relate to calculation of dose rates in air from beta emitters associated with an infinite plane of negligible

thickness. Hine and Brownell[3.2] described the derivation of these expressions. Briefly, an empirical expression was fitted to measurements of dose from point sources of beta particles in air. The point source kernel was then integrated over the plane surface giving Eq. (3.5). The empirical expressions selected for computation of the energy-dependent parameters ν and C were those adopted for calculations in soft tissue. Both α and C are dimensionless parameters. Surface contamination in units of $\mu Ci/cm^2$ are used in the calculations.

3.1.4 Gamma Radiation from a Contaminated Surface[3.3]

$$D_i(t) = 827\ N\ \sigma E_m B_s E_1(\sigma x) \qquad \text{(rem/hr)}, \qquad (3.10)$$

where

$D_i(t)$ = dose rate due to ith radionuclide (rem/hr),

x = distance above ground surface (cm),

N = level of ground contamination ($\mu Ci/cm^2$),

σ = linear energy absorption coefficient (cm^{-1}),

E_m = energy of gamma radiation (Mev),

B_s = backscatter correction for body immersed in air, and

$E_1(\sigma x)$ = the E_1 function for the argument σx.

Equation (3.10) is used to calculate dose rates in air from gamma emitters associated with an infinite plane of negligible thickness. The backscatter correction for a body immersed in air is assumed to be 1.14.

3.2 Approach for Preparing Radionuclide Lists

The models have been programmed for computer calculations of external beta and gamma doses from submersion in contaminated air, submersion in contaminated water, and external radiation at heights of 0.9 in., 2.5 ft., and 5 ft. above contaminated ground surfaces. In these analyses, dose

rates were calculated at times of 0, 13 weeks, 1 year, 30 years, and 50 years; accumulated doses were calculated at times of 13 weeks, 1 year, 30 years, 50 years, and infinity. The computer output includes a listing of radionuclides according to dose rate and total dose for each specified condition of time and distance. Beta and gamma exposures were also summed by radionuclides and listed for each mode of exposure.

A total of 176 radionuclides was selected for preliminary calculations of external dose. The selected fission products were assumed to result from thermal fission of ^{235}U and only those parent radionuclides with a physical half-life greater than 10 minutes and yield greater than 0.01% were included. Appendix II contains the published data on pertinent nuclear properties of each radionuclide considered in these dose calculations. The references at the end of Appendix II were used in the order listed in assembling these data. External dose rates and total doses were calculated for concentrations of 1 μCi/g in air and water, and 1 $\mu Ci/cm^2$ of contaminated surface to permit adaptations to future dose estimates.

References for Chapter 3.0

3.1. K. Z. Morgan, Health Control and Nuclear Research, External Exposure, unpublished.

3.2. G. J. Hine and G. L. Brownell, "Discrete Radioisotope Sources," p. 694 in Radiation Dosimetry, Academic Press, Inc., New York, 1956.

3.3 K. Z. Morgan and J. E. Turner (eds.), "Dose from External Sources of Radiation," in A Textbook in Health Physics, in manuscript.

4.0 INTERNAL DOSE ESTIMATIONS

Internal dose estimation for a population requires careful consideration of situations affecting each of the population groups. Undoubtedly the occupational situation, involving only the working adult segment of the population for which the "standard man" concept was developed, has received most attention in the past and is the exposure situation which is best understood. Internal dose models used in this report are based on a modified version of the "standard man" concept given in ICRP Publication No. 2.[4.1] Where data are available and indicate significant differences in the dose to be expected in various age groups, these data are being used, and since many of the problem areas are under active research currently, more such data may be available within the next few years. However, it is recognized that although the present models used to estimate dose to the population include much of the flexibility and special consideration necessary to obtain valid dose estimates for all population groups, there remain many unsolved problems which can only be handled now by using conservative assumptions.

4.1 Dose Models

4.1.1 All Organs Except G.I. Tract

A modified form of the following general expression was used for all organs other than the G.I. tract:

$$D_{it_{sm}} = \frac{I_{i_o} e^{-\lambda_{ri}\tau} \, 51\epsilon_i T_{ei} f_i}{m(0.693)} \left[1 - e^{-\lambda_{ei} t} \right] \quad \text{(rem)} , \qquad (4.1)$$

where

$D_{it_{sm}}$ = accumulated dose (rem) to the organ of interest for "standard man" (sm) from the ith radionuclide during the first t days following intake,

51 = constant = (dis/day) (g/rad/Mev)μCi,

ϵ_i = effective absorbed energy (Mev) of the ith radionuclide per disintegration in the organ of interest,

f_i = fraction of the ith radionuclide taken into the body that arrives in the organ of interest,

I_{i_o} = intake (μCi) of the ith radionuclide corrected to the time of detonation,

m = mass (g) of the organ of interest,

T_{ei} = effective half-time (days) of the ith radionuclide in the organ of interest,

λ_{ei} = effective elimination constant (days^{-1}) of the ith radionuclide in the organ of interest,

λ_{ri} = radioactive decay constant (days^{-1}) of the ith radionuclide,

τ = post-excavation time (days) at start of exposure, and

t = post-intake time (days).

In this expression, the term $I_{i_o} e^{-\lambda_{ri}\tau}$ provides a means for calculating the reduced dose commitments (due to radioactive decay, with no allowance for environmental redistribution of radionuclides) which would result if radionuclide intake occurred at various post-detonation times. Calculation of dose to the lungs following inhalation of an insoluble radionuclide is a special case of the expression. In this case, the present ICRP lung

model suggests setting the value of f_i at 0.125 and calculating T_{ei} assuming a biological half-time in the lungs of 120 days (plutonium and thorium, with biological half-times of 1 and 4 years, respectively, are exceptions).[4.1]

In Eq. (4.1) the parameters I_{i_o}, T_{ei}, f_i, and m are clearly ones which can be expected to change significantly with age. The value of ϵ_i may also vary with age, because the size of the organ changes with age, and the effective radius of the organ is one of the factors considered in the evaluation of ϵ_i. In estimating population doses, it is likely that changes in ϵ_i will be of less significance than will changes in the other age-dependent parameters. However, ϵ_i may vary by as much as a factor of 2 in some cases. The variation of these parameters with age is complicated by the influence of such factors as climate, diet, and personal habits.

Information on the age-dependence of many of the parameters of "standard man" is available; for example, mass of total body and of body organs as a function of age, elemental composition of body organs, daily intake and excretion of the elements, and variations in daily intake of numerous dietary components with age.[4.2] Figures 4.1 and 4.2 illustrate the type of data available on body and organ mass as a function of age for the Caucasian.[4.3, 4.4] Figure 4.3 gives the daily water intake as a function of age for a Caucasian population in a temperate climate.[4.2] These data can be used to adjust dose calculations to account for changes in organ mass (m) as a function of age. Assuming that the age-dependent intake of radionuclides by ingestion and inhalation are directly proportional to water and air intakes, respectively, dose calculations can be

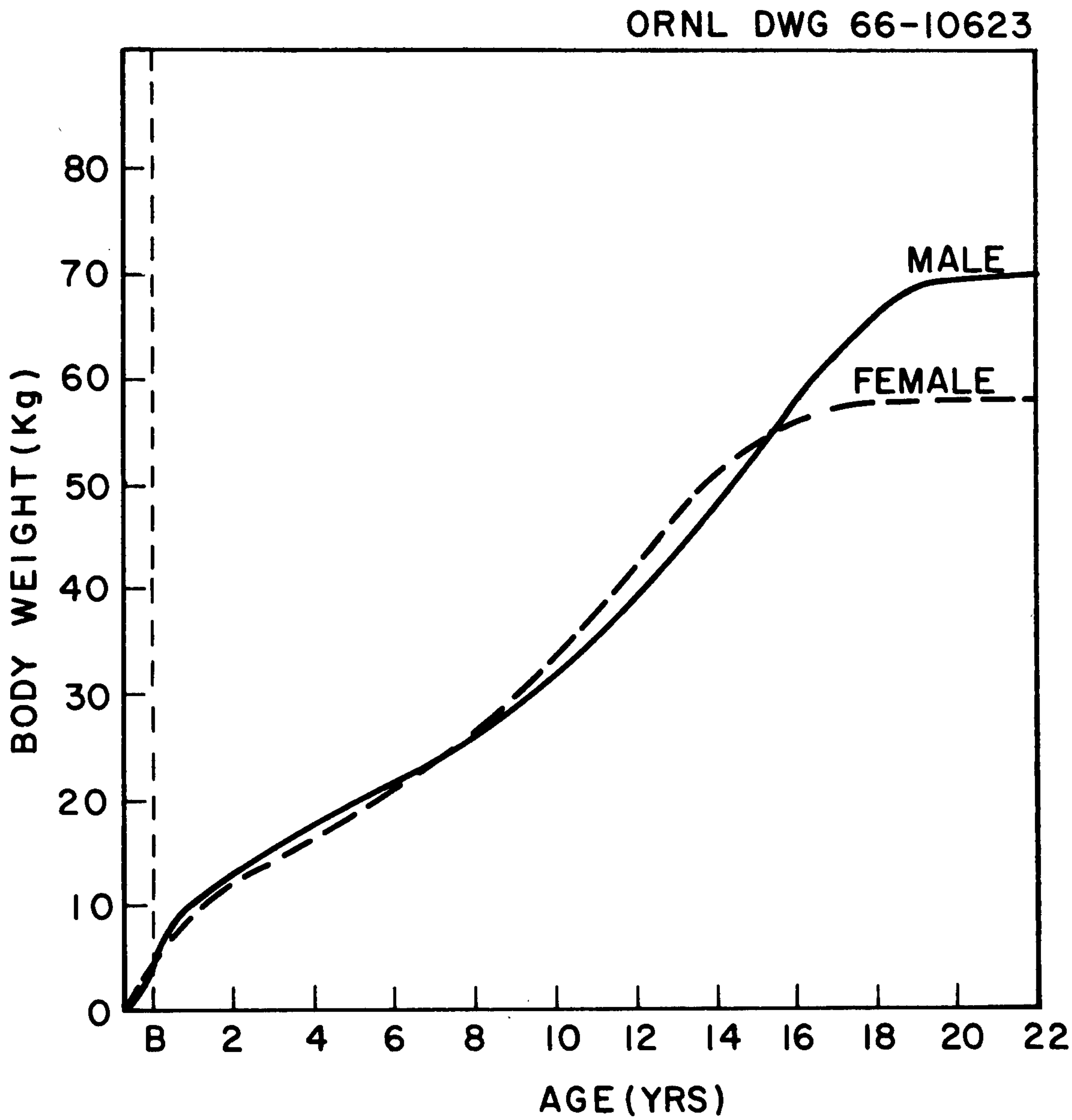

Fig. 4.1. Weight of Total Body as a Function of Age.

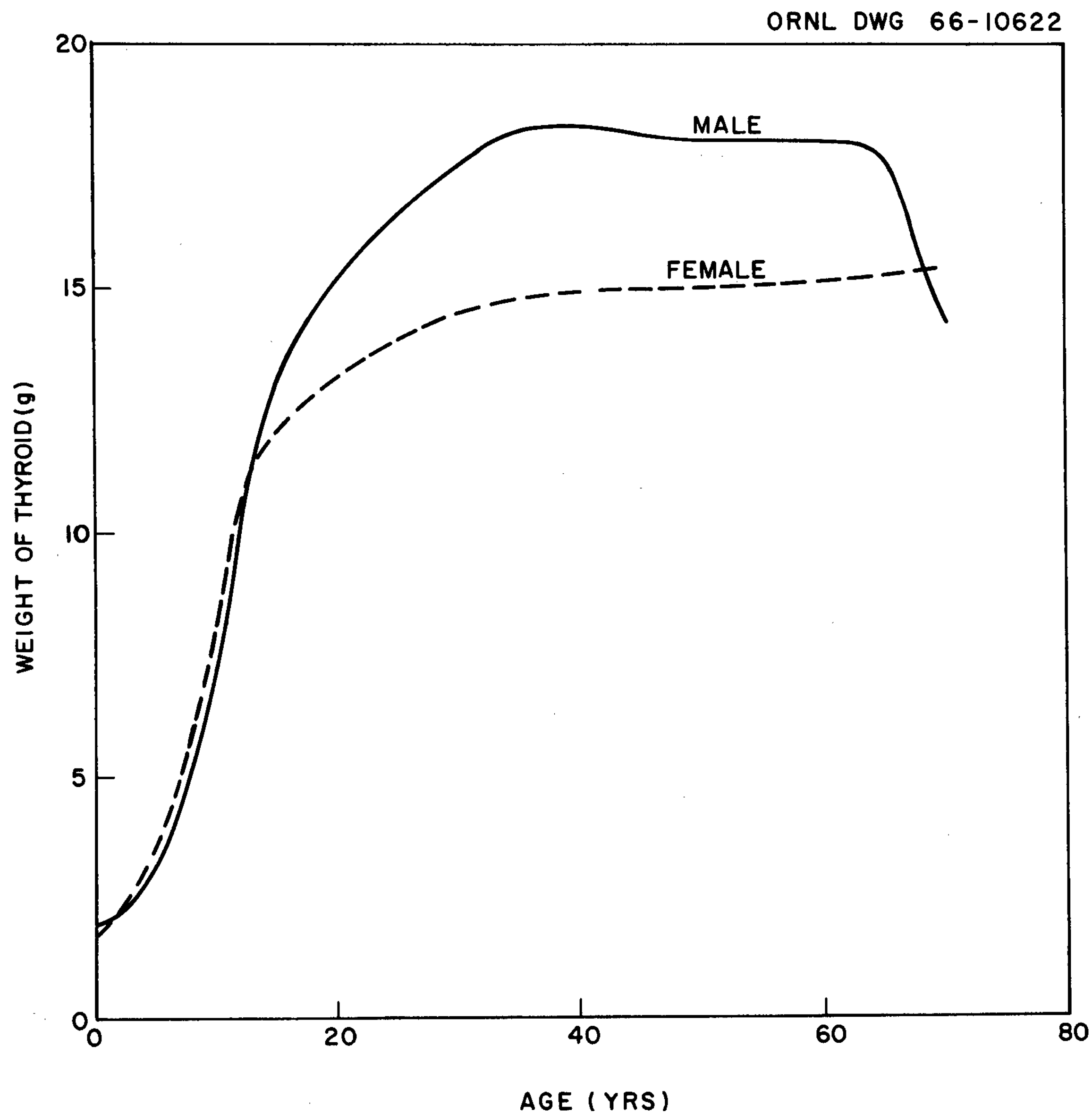

Fig. 4.2. Weight of Thyroid Gland as a Function of Age.

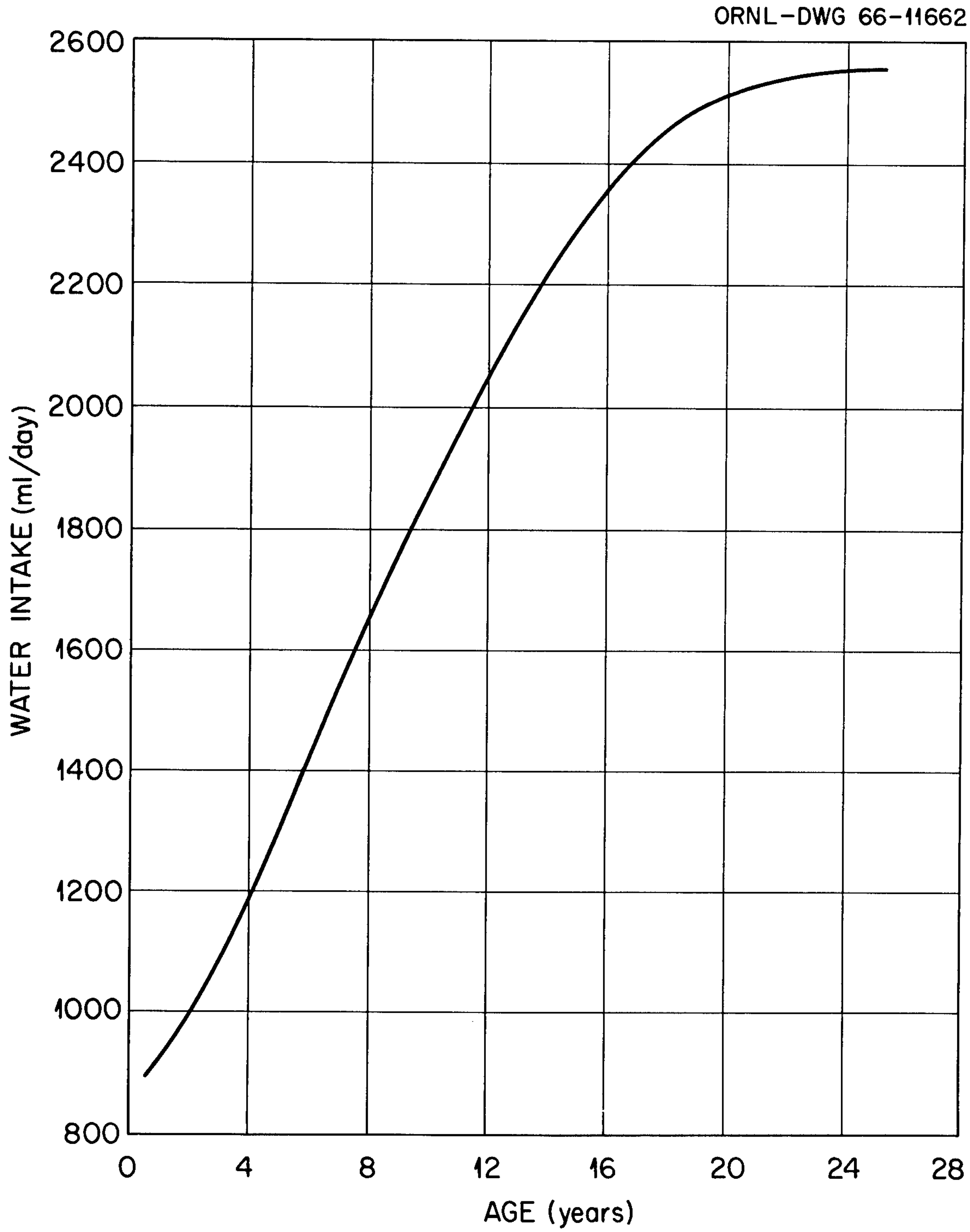

Fig. 4.3. Daily Water Intake as a Function of Age.

adjusted to include the effect of age upon radionuclide intake (I_{i_o}). As stated above, the effective absorbed energy per disintegration (ϵ_i) may change as the mass of the organ changes with age. This change in ϵ_i can be calculated; the significance of the change depends upon the organ and the radionuclide. To date, only the values of ϵ_i for "standard man" given in ICRP Publication No. 2 have been used. Lack of information prevents adjustment of the other age-dependent variables, T_{ei} and f_i, with the exception of a very few radionuclides such as ^{131}I and ^{90}Sr. The "standard man" concept was modified in Phase I to include the age-dependence of radionuclide intake and organ mass, but ϵ_i, T_{ei}, and f_i were fixed at "standard man" values.

The age-dependent modification of Eq. (4.1) can be written as

$$D_{it\gamma} = h_\gamma D_{it_{sm}} \qquad \text{(rem)}, \tag{4.2}$$

where

$D_{it\gamma}$ = accumulated dose (rem) to the organ of interest for an individual of age γ at time of intake from the ith radionuclide during the first t days following intake,

h_γ = factor to modify the "standard man" dose for the effect of age upon radionuclide intake and organ mass, and

$D_{it_{sm}}$ is the same as defined in Eq. (4.1). The rem dose from the ith radionuclide to an individual of age γ at the time of intake is equal to the rem dose from the ith radionuclide calculated for standard man multiplied by a modification factor h_γ. The modification factor is

$$h_\gamma = \frac{S_\gamma / S_{sm}}{M_\gamma / M_{sm}} \quad , \tag{4.3}$$

where

S_γ = daily intake (cm^3/day) of air or water for an individual of age γ,

S_{sm} = daily intake (cm^3/day) of air or water for "standard man",

M_γ = mass (g) of the organ of interest for an individual of age γ, and

M_{sm} = mass (g) of the organ of interest for "standard man".

The age-dependency factor (h_γ) is the same for all radionuclides because daily radionuclide intake (the only radionuclide-dependent term in the factor) was assumed to be proportional to daily water and air intakes. The age-dependent parameters in the dose expression [Eq. (4.1)] were fixed at the "adult" values.

Evaluation of h_γ requires use of the appropriate values of S_γ and M_γ, depending upon the age of the individual at the time of radionuclide intake, and the post-intake period for which the dose is being calculated.

4.1.2 G. I. Tract

A simple method for calculation of dose to the G.I. tract was modified from the work of Dolphin *et al.*[4.5] The dose is given by

$$D_{i\gamma} = h_\gamma \frac{e^{-\lambda_{ri}\tau}(0.3)}{I'(MPC)_i} \qquad (rem/\mu Ci), \qquad (4.4)$$

where

0.3 = the dose rate (rem/week) delivered to some part of the G.I. tract from a weekly intake at the MPC,

I' = weekly intake (cm^3/week) of water for ingestion calculations and weekly intake of air for inhalation calculations, and

$(MPC)_i$ = maximum permissible concentration ($\mu Ci/cm^3$) of the ith radionuclide in water or air for continuous exposure; water values used for ingestion calculations and air values for inhalation calculations.

$D_{i\gamma}$ is the dose in rem/μCi from the ith radionuclide to some part of the G. I. tract of an individual of age γ at the time of radionuclide intake. The terms h_γ, λ_{ri}, and τ are as defined previously.

4.2 Approach for Preparing Radionuclide Lists

4.2.1 Use of Models

The modified internal dose models were used in a series of calculations for listing the radionuclides in order of relative hazard. The primary purpose of this listing was to assist in selecting a workable number of radionuclides which will be given further and more detailed consideration. These radionuclides should represent a large part of the total internal dose commitment to the populations being considered. For this listing, a single intake of 1 μCi was assumed for "standard man". The radionuclide intake of an individual less than 20 years of age will be less than 1 μCi, as determined by the ratio of his daily water or air intake to that of a 20-year old. The dose commitment subsequent to intake was calculated over time periods of one year to facilitate yearly adjustment of organ mass as a function of age. The accumulated dose up to any time t in the post-intake period is the summation of a series of yearly doses. Initial listing was done by organ from calculations of dose to each of the major organs for every radionuclide considered. These calculations are of interest because the total internal dose commitment to any organ is the sum of the dose contributions to that organ from all of the radionuclides involved.

4.2.2 Selection of Radionuclides and Body Organs

The radionuclides considered were selected from unclassified literature on induced activities and fission products resulting from thermal fission of ^{235}U. Selection was influenced by the availability of detailed information for the particular radionuclide in ICRP Publication No. 2.

The body organs considered are as follows: total body, muscle, bone, spleen, G.I. tract, liver, kidneys, testes, ovaries, thyroid, and lungs. This list includes the major organs of primary concern at present, and it encompasses those organs for which the greatest amount of detailed information appears in ICRP Publication No. 2.

4.2.3 Selection of Values for γ, τ, and t

Current standards and recommendations of various radiation protection authorities were consulted in the selection of intake ages (γ) to be considered. Intake ages chosen are 0.5, 3.5, 10.5, and 20.5 years. Change in radiation dose as a function of age at time of intake is of special interest. It seems likely that for many radionuclides the critical age group will be the young of the population. Therefore, the consideration of age-dependent parameters is essential for the establishment of feasibility criteria.

Post-detonation intake times (τ) were arbitrarily chosen to be 60 days, 1 year, and 5 years.

Post-intake time periods (t) for which accumulated doses have been computed are 1 year, 30 years, and 70 years. The yearly dose was desired because it is commonly used in radiation protection guides. The 30-year

figure was chosen to determine the dose commitment to an individual during the first 30 years of life as an estimate of the genetic dose to the population. The value of 70 years was chosen to estimate the maximum dose commitment to an individual living in the canal area.

4.3 Refinement of Dose Calculations for Critical Radionuclides

The dose calculations used in the search for critical radionuclides will be reviewed for possible further refinement. Effort will be centered on the age-dependent variables pointed out previously in Eq. (4.1). The degree of refinement will be limited by the availability of input information. Results of preliminary work with HTO and ^{131}I illustrate refinements which can be made if the necessary information is available.

4.3.1 Tritiated Water (HTO)

Tritiated water (HTO) will receive much consideration in this feasibility study. The dose to the body water pool from a unit intake of HTO may be calculated using Eq. (4.1).

Setting: $t = \infty$,

$\tau = 0$,

$I_{i_o} = 1\ \mu Ci$,

$m = W$ (g of total body water), and

$f_i = 1$,

the expression becomes

$$D_\infty = 51\epsilon T_e/0.693W \qquad \text{(rem)}. \tag{4.5}$$

Because of the very short range of the tritium β-particle, it is clear that changes in the size of the body water pool with age will not change ϵ. The age-dependent and age-independent parameters in Eq. (4.5) may be separated as follows:

$$D = \underbrace{(51\epsilon/0.693)}_{\text{independent}} \qquad \underbrace{(T_e/W)}_{\text{dependent}} \qquad \text{(rem)}.$$

The equilibrium relationship between pool size of body water, daily water intake, and the rate constant for the turnover of body water can be expressed by

$$W = I'/\lambda_b \ , \tag{4.6}$$

where

I' = daily water intake (cm^3/day), and

λ_b = biological elimination constant for body water ($days^{-1}$).

A uniform distribution in body water can be assumed because HTO taken into the body equilibrates with the body water in less than one hour. The rate constant λ_b may be replaced by $0.693/T_b$ and the expression rearranged to yield

$$T_b/W = 0.693/I' \quad . \tag{4.7}$$

T_b is the biological half-time of water in the body water pool. Tritium has a radioactive half-life of 12.3 years, and water has a biological half-time in man of approximately 12 days; therefore, T_b and T_e are essentially equal in this case. Replacing T_b with T_e and substituting from Eq. (4.7) into Eq. (4.5) gives

$$D_\infty = 51\epsilon/I' \qquad \text{(rem)}. \tag{4.8}$$

The infinite rem dose to the body water from an intake of 1 μCi of HTO is related to only one age-dependent variable in Eq. (4.8). The rem dose as a function of age for a 1 μCi intake of HTO was calculated in two ways, using Eq. (4.5) and Eq. (4.8), respectively. Equation (4.5) requires knowledge of both T_e and W as a function of age. Such information is available only for W, so T_e was fixed at its "standard man" value. Equation (4.8) requires only knowledge of daily water intake as a function of age; that information is available for Caucasian populations, as shown in Fig. 4.3. The results of the calculations are shown in Fig. 4.4. Comparison of the two curves in Fig. 4.4 indicates that a considerable over-estimation of dose is made at the younger ages when T_e is assumed to be constant. It is apparent that T_e must vary considerably with age. This example illustrates the value of information on other age-dependent parameters as a supplement to the body and organ mass changes observed with age.

The calculation of dose for HTO can be refined further with one additional change. Set

$$I_{i_o} = I'C \quad (\mu Ci/day) ,$$

where

I' = daily water intake (cm^3/day), and

C = concentration of HTO in the water ($\mu Ci/cm^3$).

The final dose expression for a daily intake reduces to

$$D_\infty = 51C\varepsilon \qquad (rem). \tag{4.9}$$

This expression can be used to determine the dose commitment from ingestion of HTO as a function of intake concentration, avoiding the age-dependent parameters. Equation (4.9) represents only the dose due to

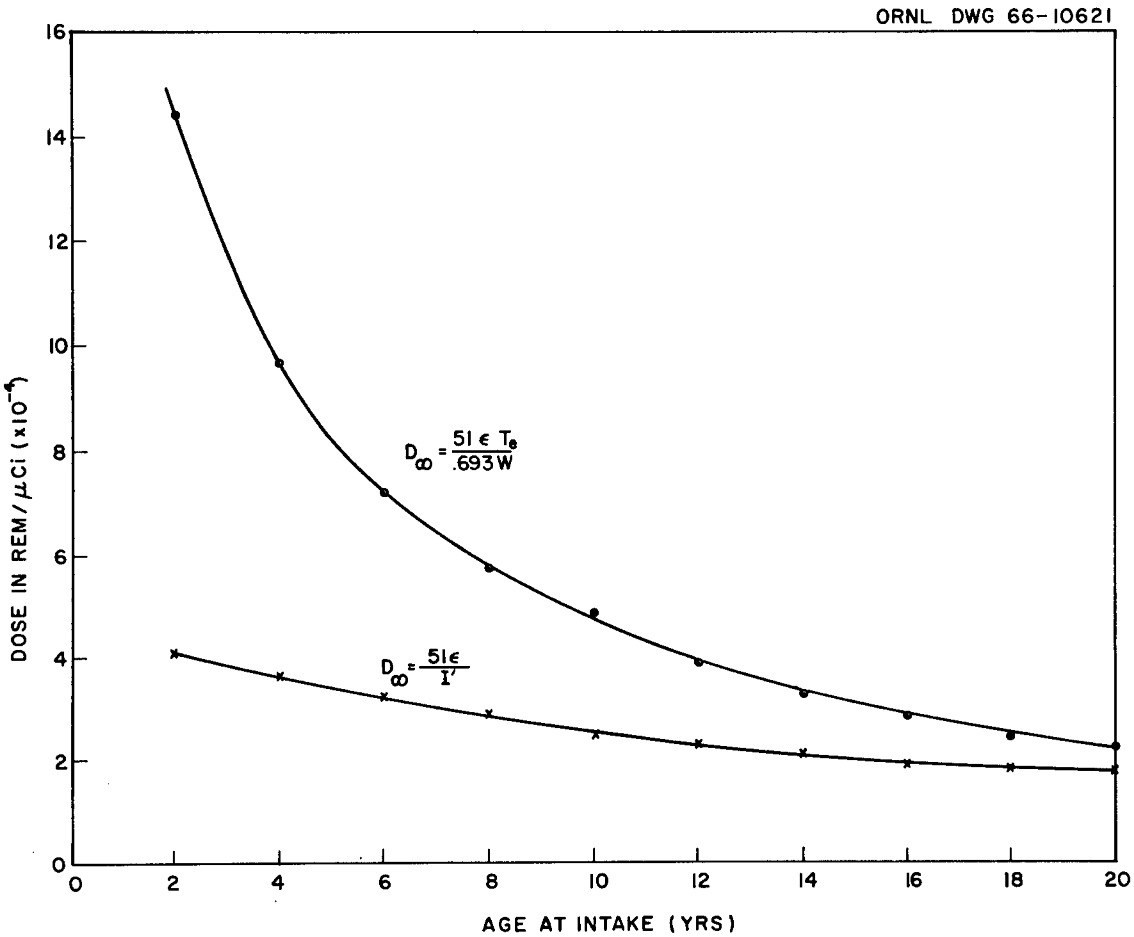

Fig. 4.4. Dose to the Body Water from 1 μCi of HTO as a Function of Age at Time of Intake. The upper curve was calculated with a dose expression containing two age-dependent parameters, mass of the body water (W = 60% of total body weight) and effective half-time of HTO in the body water (T_e). Lack of information necessitated setting T_e at the "standard man" value. The dose expression for the lower curve contains only one age-dependent parameter, daily water intake (I').

intake for a period of one day. It is conservative in that it assumes all the water intake is contaminated to the level C. If this is not the case [e.g., if a certain factor (f) of the daily intake is from imported, noncontaminated foods and beverages], then the factor (1 - f) could be introduced here. Direct evidence on the habits of these populations or individuals would be needed to justify such a reduction. The dose commitment is determined by summing a series of dose calculations for individual intakes when C varies as a function of time.

This example is unique to HTO in many respects but it illustrates two important points. First, dose calculation refinements can identify the minimum input data which are needed. Second, the application of "standard man" parameters to younger segments of the population can lead to sizable errors in the estimates of dose commitment.

4.3.2 Radioiodine (^{131}I)

A considerable amount of information is available describing ^{131}I metabolism. Figures 4.5 and 4.6 present some of these data. Thyroid uptake of iodine is the only parameter presented which does not seem to vary significantly with age. These data were used in Eq. (4.1) for calculation of the infinite rem dose to the thyroid as a function of age at time of ^{131}I intake. Intake was set at 1 μCi. The results of these calculations are given in Fig. 4.7. Mass of the thyroid was the only age-dependent variable evaluated in the uppermost curve, all others were fixed at their "standard man" values. Mass of the thyroid and effective half-time of iodine in the thyroid were varied with age in generating the middle curve. Mass of the thyroid, effective half-time of iodine in the thyroid, and daily intake were varied with age in the bottom curve,

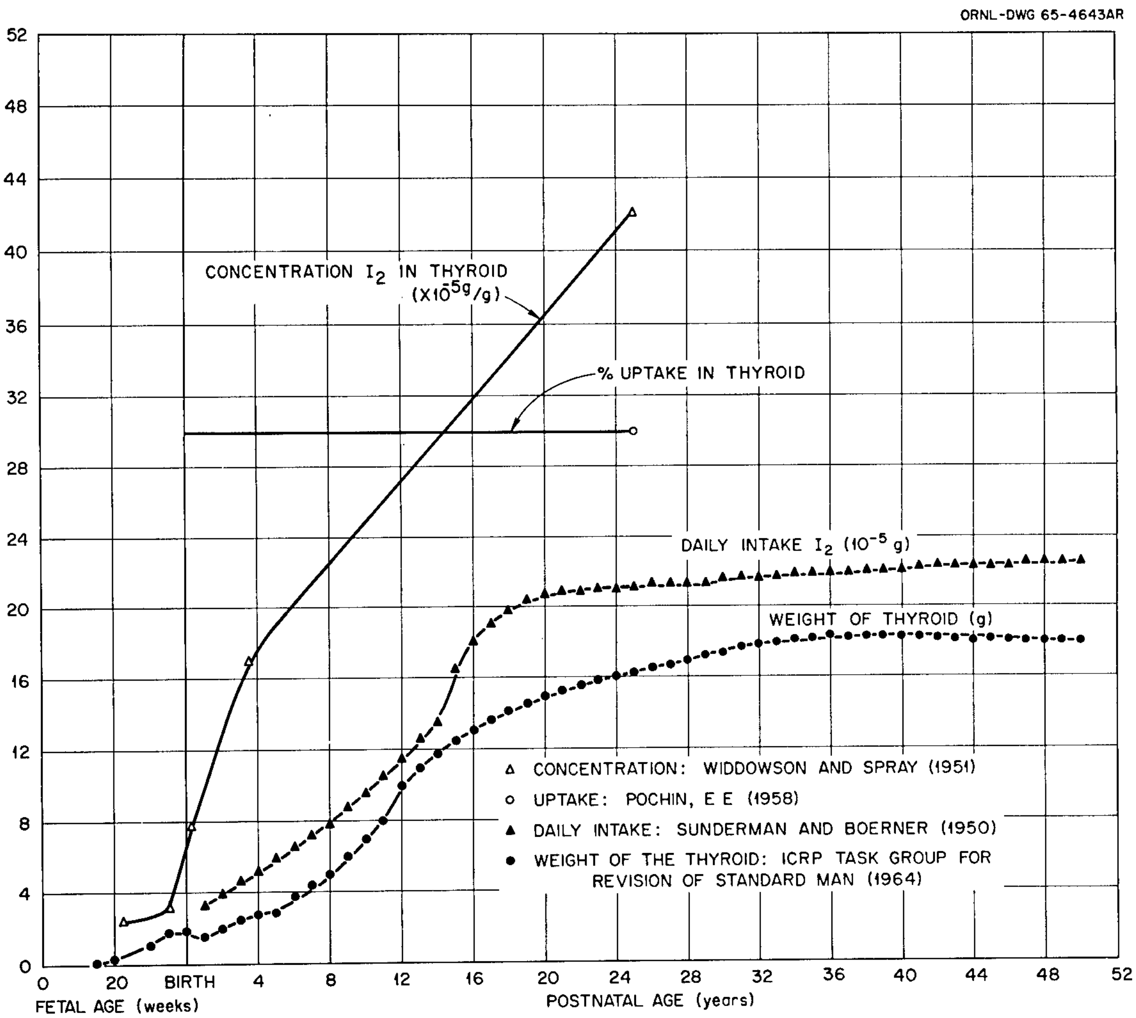

Fig. 4.5. Change in Metabolic Rate of Iodine as a Function of Age.

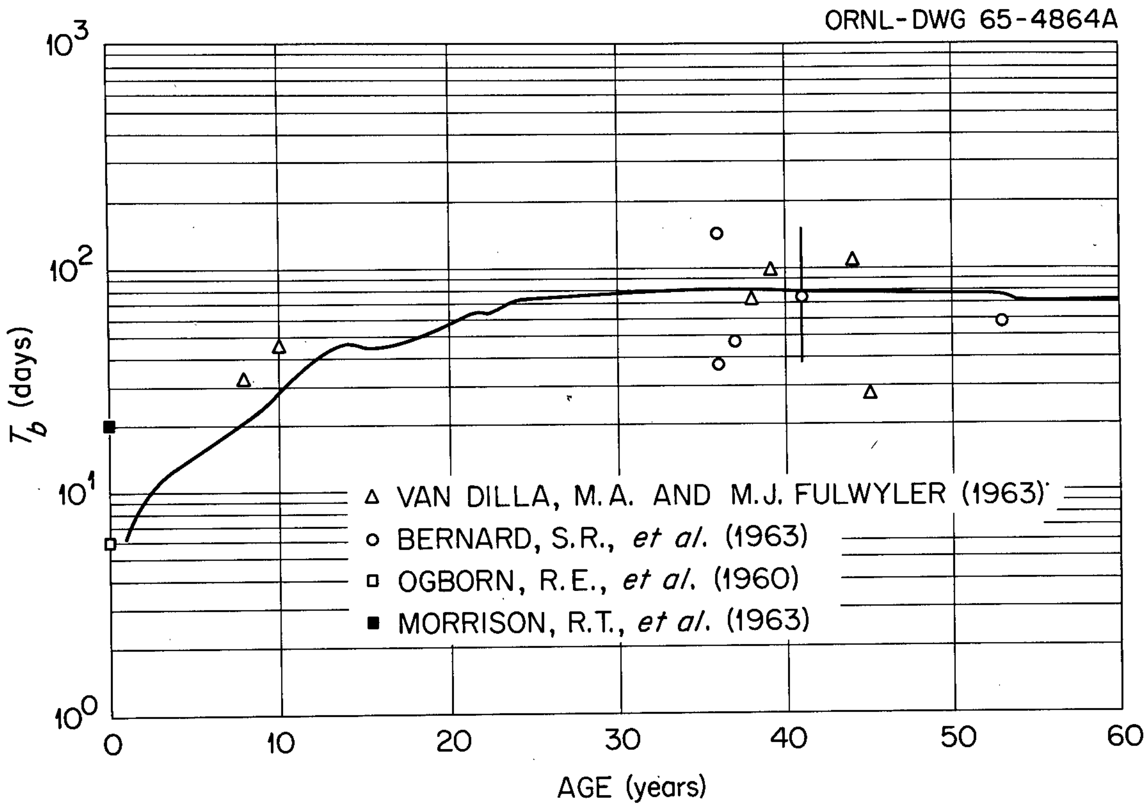

Fig. 4.6. Variation of Biological Half-Time of Iodine as a Function of Age.

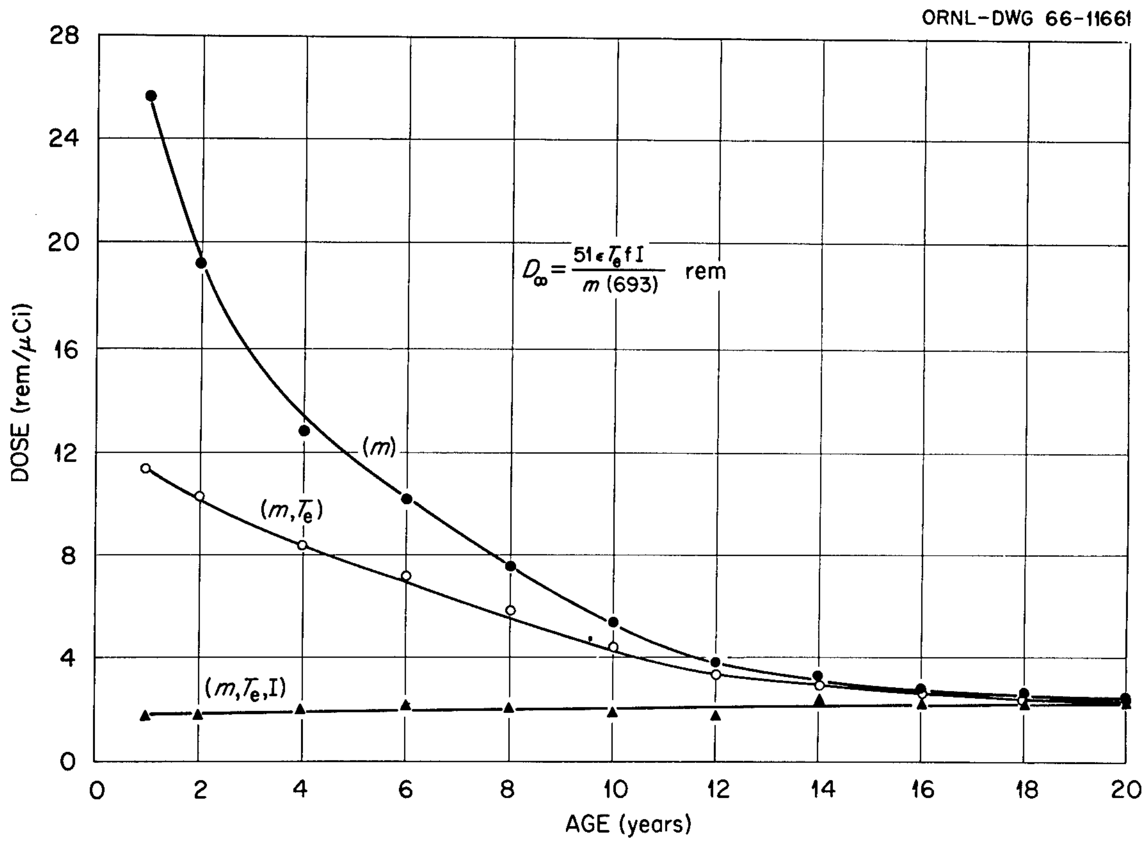

Fig. 4.7. Dose to the Thyroid from 1 μCi of ^{131}I as a Function of Age at Time of Intake. Three of the age-dependent parameters in the dose expression [mass of the thyroid (m), effective half-time of ^{131}I in the thyroid (T_e), and daily iodine intake (I)] were evaluated as functions of age for the curves as identified. All other parameters in the dose expression were fixed at "standard man" values.

leaving the energy term as the only age-dependent parameter uncorrected. This intake adjustment, based on daily iodine intake rather than daily water or air intake, assumes the same pathway to man for all iodine. Radionuclides released to the environment by nuclear excavation could follow pathways to man different from those followed by their normal dietary counterparts.[4.6] The curves in Fig. 4.7 illustrate the importance of evaluating each of the age-dependent parameters. Unfortunately, the data required for such adjustments are either scarce or non-existent for most other radionuclides. Ideal calculations would use data specific for the populations living in the canal area.

4.4 Application of the "Standard Man" Concept to the Indigenous Populations of the Canal Area

The models for estimation of internal dose presented in this report, and the data upon which they are based, are referenced to the Caucasian population from which "standard man" was drawn. This feasibility study requires internal dose estimates for the indigenous populations of the canal area, populations which differ considerably from a Caucasian population. Lack of literature describing the populations in the canal area makes it difficult to form even gross comparisons between their adult segments and "standard man". Table 4.1 contains data accumulated to assist in this comparison. The blank areas in the table emphasize the need for more information. This table would be of greater value if it could be extended to include more body organs.

Table 4.1. Comparative Data to be Used in Determining Standard Man Parameters for Various Populations

Parameter	Caucasian[a,b] (1)	Indian[c,d,e] (2)	Ratio (2)/(1)	Cuna[f,g] (3)	Ratio (3)/(1)	Choco[f] (4)	Ratio (4)/(1)	Colombian[h] (5)	Ratio (5)/(1)
Weights(g):									
Total Body	70,000	46,000	0.66	54,000(10)[i]	0.77				
Stomach	250	170	0.68						
Liver	1,700	1,130	0.66						
Brain	1,500	1,240	0.83						
Lungs(2)	1,000	810	0.81						
Kidneys(2)	300	220	0.73						
Heart	300	230	0.77						
Spleen	150	140	0.93						
Pancreas	70	100	1.43						
Testes(2)	40	45	1.13						
Thyroid	20	11	0.55						
Prostate	20	36	1.80						
Adrenals(2)	20	12	0.60						
Heights(cm):									
Male	176	161	0.91	154(70)	0.88	157(81)	0.89	164	0.93
Female	162	151	0.93	144	0.89	144(30)	0.89	157	0.97
Adult	169	156	0.92	149	0.88	150	0.89	160	0.95
Air Inhaled(cm^3):									
8 hr. work day	10^7								
16 hrs.not at work	10^7	1.37×10^7	1.37						
Total	2×10^7								
Water Intake(cm^3):									
Food/day	1,000								
Fluids/day	1,200								
Total	2,200	4,500	2.04						

[a]International Commission on Radiological Protection, Report of Committee II on Permissible Dose for Internal Radiation, ICRP Publ. 2, Pergamon Press, London (1959); Health Phys. 3 (June 1960).

[b]National Center for Health, Statistics Ser. II, No. 8 (1965).

[c]K. Venkataraman, V.M. Raghunath, K.Santhanan, and S.Somasundaram, Physiological Norms in Indian Adults - Data on Total Body Weight and Weights of Twelve Body Organs, AEET/HP/Th-21 (1964).

[d]V.M.Raghunath, K.Venkataraman, H.S.R.C.Murthy, and S.Somasundaram, Health Phys. 11, 287 (1965).

[e]K.Venkataraman, S.Somasundaram, and S.D.Soman, Health Phys. 9, 647 (1963).

[f]A.Hadlicka, Am. J. Phys. Anthropology 9, 1 (1926).

[g]C.Keeler, Letter to E.G. Struxness (1966).

[h]Interdepartmental Committee on Nutrition for National Defense, Colombia Survey, Wash., D.C. (Dec. 1961).

[i]Numbers in parentheses denote number of observations.

References for Chapter 4.0

4.1 International Commission on Radiological Protection, Report of Committee II on Permissible Dose for Internal Radiation, ICRP Publ. 2, Pergamon Press, London (1959); Health Phys. 3 (June 1960).

4.2 Report of ICRP Task Group on the Revision of Standard Man, in preparation.

4.3 E. Boyd, Outline of Physical Growth and Development, Burgess Co., Minn. (1941).

4.4 Y. Mochizuki, R. Mowafy, B. Pasternack, Health Phys. 9, 1299 (1963).

4.5 G. W. Dolphin, A. Fairbairn, and T. Murphy, Accumulated Dose Received in 13 Weeks and 50 Years by Body Tissues from One Microcurie Single Intake by Inhalation or Injection through a Wound, AHSB (RP) R 20 (August 2, 1962).

4.6 H. N. Wellman, B. Kahn, A. Salem, and P. J. Robbins, Health Phys. 12, 1791 (1966).

5.0 SEARCH FOR CRITICAL RADIONUCLIDES

The purpose of preparing an ordered list of radionuclides is to provide guidance on the identification of radionuclides that will require detailed study in the field because of their potential relative hazard to humans. This search for critical radionuclides is divided into the following four steps:[a]

(1) Radionuclide Dose Commitment List -- An ordered arrangement of radionuclides according to a) external dose commitment from 1 μCi per g of water, per g of air, and per cm^2 of ground surface; and b) internal dose commitment from a 1 μCi single intake by inhalation and ingestion. A Radionuclide Dose Commitment List does not consider production, venting, or environmental exposure pathways.

(2) Radionuclide Dose Commitment Index -- An ordered arrangement of radionuclides derived from a Radionuclide Dose Commitment List by the incorporation of production and venting estimates. An index does not include adjustments based on fallout predictions or environmental exposure pathways. The Relative Significance Index used by BMI[5.1] is a special treatment of a Radionuclide Dose Commitment Index because it was normalized to a chosen radionuclide.

---

[a]Only the first step is taken in this document. Steps 2, 3, and 4 will be reported in subsequent ORNL documents.

(3) Preliminary Radionuclide Rank -- An ordered arrangement of radionuclides derived from a Radionuclide Dose Commitment Index by the incorporation of information on initial distribution in time and space. A Preliminary Radionuclide Rank uses fallout predictions, but does not include adjustments for environmental exposure pathways.

(4) Final Radionuclide Rank -- An ordered arrangement of radionuclides derived from a Preliminary Radionuclide Rank by the incorporation of best estimates of environmental exposure pathways.

The sections which follow in this chapter deal with Radionuclide Dose Commitment Lists.

5.1 External Dose

Six Radionuclide Dose Commitment Lists, computed for external exposures, are included in Appendixes III through VIII. Each listing considered 1 μCi of the radionuclide per g of water or air, or per cm^2 of ground surface; and the listings were based on dose rates at time zero (no radioactive decay of 1 μCi per g of water or air, or per cm^2 of ground surface) and total doses accumulated over 50 years (corrected for decay of 1 μCi per g of water or air, or per cm^2 of ground surface) for submersion in contaminated water, for submersion in contaminated air, and for external exposures at 2.5 feet above the contaminated ground surface. The Radionuclide Dose Commitment Lists were arranged by the computer in decreasing order for dose rate (rems/hr) and for total dose (rems) in each

of the Appendixes. These computer outputs are in computer E format, where, for example, E01 represents the factor 10 raised to the first power. Thus, in Appendix III, the dose rate due to submersion in water containing 1 μCi/g of ^{24}Na is 9.39 rems/hr.

The computer outputs have been analyzed to select radionuclides of potential short-term hazard (Table 5.1) and potential long-term hazard (Table 5.2). Table 5.1 lists radionuclides which produce a total dose greater than 10 rems in 13 weeks, or less, from submersion in water. Table 5.2 lists radionuclides which contribute greater than 1% of background radiation (1.2×10^{-5} rems/hr after 1 year of radioactive decay). All radionuclides in the Relative Significance Index developed by the Lawrence Radiation Laboratory for internal dose are included in Tables 5.1 and 5.2.[5.1] A similar indexing developed by BMI includes ^{56}Mn and ^{204m}Pb, which are not found in either of these tabulations.[5.2]

5.2 Internal Dose

5.2.1 Radionuclide Dose Commitment List by Organ

Radionuclides were listed in descending order of dose commitment for each of the body organs considered. The dose to the organ per μCi of intake was the basis for listing. Many listings were generated despite the very limited number of values selected for γ, τ, and t, as described in section 4.2.3. ICRP Publication No. 2 does not provide the information required for the internal dose model [Eq. (4.1)] for calculation of dose to every organ from each radionuclide. The dose calculated with total body as organ of reference was used whenever information for a specific organ-radionuclide combination was not available.

Table 5.1. Total Submersion Dose in Contaminated Water Received in 13 Weeks or Less from an Initial 1 μCi of Parent Radionuclide/g of Water

No.	Radionuclide	rems	No.	Radionuclide	rems
1	^{48}Sc	472	14	^{149}Pm	77.2
2	^{125}Sn - ^{125}Sb - ^{125}Te	384	15	^{99}Mo - ^{99m}Tc	69.2
3	^{131}I - ^{131m}Xe	364	16	^{195m}Pt	61.9
4	^{132}Te - ^{132}I	340	17	^{187}W	61.2
5	^{127}Sb - ^{127}Te	295	18	^{97}Zr - ^{97m}Nb - ^{97}Nb	59.8
6	^{147}Nd - ^{147}Pm	289	19	^{143}Ce - ^{143}Pm	52.4
7	^{196}Au	227	20	^{133}I - ^{133m}Xe - ^{133}Xe	52.1
8	^{24}Na	204	21	^{133}Xe	51.1
9	^{143}Pr	157	22	^{203}Pb	42.7
10	^{131m}Xe	144	23	^{239}Np	41.8
11	^{198}Au	116	24	^{85m}Kr - ^{85}Kr	41.6
12	^{111}Ag	115	25	^{91}Sr - ^{91m}Y	41.5
13	^{237}U	91.5	26	^{126}Sb	40.8

Table 5.1., continued

No.	Radionuclide	rems	No.	Radionuclide	rems
27	^{93}Y	40.1	35	^{105}Rh	20.4
28	^{135}I - ^{135m}Xe - ^{135}Xe	39.7	36	^{132}I	16.6
29	^{133m}Xe	39.6	37	^{152}Eu	14.7
30	^{42}K	37.9	38	^{105}Ru - ^{105m}Rh - ^{105}Rh	14.7
31	^{153}Sm	36.6	39	^{112}Ag	12.9
32	^{151}Pm	35.3	40	^{92}Y	12.3
33	^{129}Sb - ^{129m}Te - ^{129}Te	33.3	41	^{135}Xe	11.9
34	^{88}Kr - ^{88}Rb	29.3			

Table 5.2. External Dose Rates After One Year of Radioactive Decay[a]

Radionuclide	Submersion in Water		Submersion in Air		2.5 Ft. Above Ground Surface	
	No.	rems/hr	No.	rems/hr	No.	rems/hr
^{60}Co	1	4.74	1	2.75	4	3.71(-1)[b]
^{207}Bi	2	3.36	2	1.92	8	2.82(-1)
^{134}Cs	3	2.59	3	1.54	6	3.07(-1)
^{22}Na	4	2.30	4	1.39	11	2.27(-1)
^{137}Cs - ^{137}Ba	5	1.45	7	9.35(-1)	10	2.51(-1)
^{90}Sr - ^{90}Y	6	1.13	5	1.06	1	3.06
^{106}Ru - ^{106}Rh	7	9.85(-1)	6	9.70(-1)	2	1.78
^{54}Mn	8	7.52(-1)	10	4.29(-1)	16	6.45(-2)
^{125}Sb - ^{125m}Te	9	7.43(-1)	9	4.63(-1)	15	6.99(-2)
^{210}Pb - ^{210}Bi	10	5.47(-1)	8	5.66(-1)	3	1.11
^{65}Zn	11	4.45(-1)	13	2.54(-1)	17	4.46(-2)
^{36}Cl	12	3.15(-1)	11	3.59(-1)	5	3.62(-1)
^{155}Eu	13	3.04(-1)	17	1.92(-1)	46	3.01(-7)

Table 5.2., continued

Radionuclide	Submersion in Water		Submersion in Air		2.5 Ft. Above Ground Surface	
	No.	rems/hr	No.	rems/hr	No.	rems/hr
^{85}Kr	14	2.97(-1)	12	3.04(-1)	9	2.54(-1)
^{204}Tl	15	2.16(-1)	15	2.41(-1)	7	2.96(-1)
^{115}In	16	2.13(-1)	14	2.43(-1)	13	1.59(-1)
^{113m}Cd	17	1.74(-1)	16	1.99(-1)	14	9.83(-2)
^{99}Tc	18	1.29(-1)	18	1.47(-1)	41	7.44(-3)
^{129}I	19	1.26(-1)	19	3.61(-2)	22	1.60(-2)
^{87}Rb	20	8.43(-2)	20	9.61(-2)	43	1.87(-5)
^{144}Ce	21	7.14(-2)	25	6.07(-2)	26	3.56(-3)
^{241}Pu	22	6.23(-2)	22	6.53(-2)	32	7.17(-4)
^{135}Cs	23	6.19(-2)	21	7.06(-2)	49	1.83(-8)
^{151}Sm	24	6.03(-2)	27	4.59(-2)	24	6.12(-3)
^{95}Zr - ^{95}Nb	25	5.97(-2)	28	3.59(-2)	25	5.15(-3)
^{147}Pm	26	5.48(-2)	23	6.25(-2)	12	1.71(-1)

Table 5.2., continued

Radionuclide	Submersion in Water		Submersion in Air		2.5 Ft. Above Ground Surface	
	No.	rems/hr	No.	rems/hr	No.	rems/hr
^{14}C	27	5.33(-2)	24	6.08(-2)	BKG[c]	BKG
^{93m}Nb	28	5.28(-2)	30	3.01(-2)	19	1.81(-2)
^{79}Se	29	4.69(-2)	26	5.35(-2)	BKG	BKG
^{127m}Te - ^{127}Te	30	2.69(-2)	31	2.40(-2)	20	1.73(-2)
^{240}Pu	31	2.67(-2)	33	1.52(-2)	27	3.40(-3)
^{93}Zr - ^{93m}Nb	32	2.06(-2)	29	3.12(-2)	33	7.00(-4)
^{45}Ca	33	1.78(-2)	32	2.03(-2)	44	9.35(-7)
^{181}W	34	1.75(-2)	35	9.99(-3)	30	1.26(-3)
^{239}Pu	35	1.70(-2)	36	9.67(-3)	28	2.03(-3)
^{107}Pd	36	1.07(-2)	34	1.22(-2)	BKG	BKG
^{238}Pu	37	1.01(-2)	40	5.78(-3)	23	9.50(-3)
^{55}Fe	38	9.95(-3)	41	5.68(-3)	29	1.85(-3)
^{59}Fe	39	8.95(-3)	43	5.35(-3)	31	7.52(-4)

Table 5.2., continued

Radionuclide	Submersion in Water		Submersion in Air		2.5 Ft. Above Ground Surface	
	No.	rems/hr	No.	rems/hr	No.	rems/hr
^{91}Y	40	8.44(-3)	37	9.57(-3)	18	2.85(-2)
^{89}Sr	41	5.58(-3)	38	6.37(-3)	21	1.70(-2)
^{3}H	42	5.54(-3)	39	6.32(-3)	BKG	BKG
^{185}W	43	4.76(-3)	42	5.42(-3)	34	3.15(-4)
^{35}S	44	3.08(-3)	44	3.51(-3)	BKG	BKG
^{125m}Te	45	3.06(-3)	45	1.74(-3)	36	2.17(-4)
^{203}Hg	46	2.75(-3)	46	1.73(-3)	37	2.09(-4)
^{103}Ru - ^{103}Rh	47	2.44(-3)	48	1.49(-3)	35	2.48(-4)
^{129m}Te - ^{129}Te	48	1.60(-3)	47	1.67(-3)	38	1.37(-4)
^{95}Nb	49	1.22(-3)	49	7.15(-4)	39	1.03(-4)
^{7}Be	50	1.01(-3)	50	6.26(-4)	40	9.72(-5)
^{141}Ce	51	1.36(-4)	51	1.11(-4)	42	2.13(-5)
^{51}Cr	52	7.63(-6)	52	4.35(-6)	45	6.58(-7)

Table 5.2., continued

Radionuclide	Submersion in Water		Submersion in Air		2.5 Ft. Above Ground Surface	
	No.	rems/hr	No.	rems/hr	No.	rems/hr
^{156}Eu	53	2.34(-7)	53	1.55(-7)	47	1.09(-7)
^{140}Ba - ^{140}La	54	3.77(-8)	54	1.04(-8)	50	7.51(-9)
^{32}P	55	1.68(-8)	55	1.91(-8)	48	5.69(-8)
^{143}Pr	56	3.43(-9)	56	3.91(-9)	51	7.21(-9)

[a]Dose rates after 1 yr. of radioactive decay for an initial unit quantity of parent radionuclide (i.e., 1 μCi/g of air and water, and 1 μCi/cm^2 of ground surface).

[b]Number in parentheses indicates the exponent of 10.

[c]BKG = less than 1% of natural background.

Preliminary analyses of the computer results indicated that variation of intake age (γ) did not alter greatly the radionuclide listing. The change in dose as a function of age ranged up to an order of magnitude in some cases, but variation among the individual radionuclides was insufficient to alter the listing greatly. The significance of age at time of intake, as determined by the internal dose models of this report, is influenced by the effective half-time of the respective radionuclides in the various body organs. The increase in dose commitment to younger age groups due to age-related differences in organ mass, is largest for radionuclides of short effective half-time. A large part of the dose commitment to children from a radionuclide of long effective half-time is incurred long after intake, at a time when organ masses may have reached their adult values. This influence of effective half-time introduced slight rearrangements in the listings. The influence of age upon the radionuclide listings might be different if all of the age-dependent variables in the dose models could be evaluated. Evaluation of one or more of the interrelated age-dependent variables without evaluating them all may be questioned. Nevertheless, the approach presented here, in an attempt to utilize the data presently available, seems reasonable.

Radionuclide listings were altered by increasing the length of time (τ) between device detonation and radionuclide intake, effecting a decrease in the dose commitment from the radionuclides having a short radioactive half-life. Radionuclides of short term importance may be identified in this way.

The listings were also affected by variation in the length of time (t) over which the integrated dose was calculated. Radionuclides of long effective half-time appeared higher on the list when large values of t were used.

The Radionuclide Dose Commitment Lists for individual organs are found in Appendix IX. Only listings for adults (γ = 20.5 years) are included because of the minimal differences in listings found among age groups. Listings are given for each of the body organs considered with τ and t set at 0 and 25550 days (70 years), respectively, to represent the worst possible dose commitment for an adult. On the computer output (Appendix IX) gamma (γ) is the age of the individual at time of radionuclide intake (years), tau (τ) is the elapsed time between detonation and radionuclide intake (days), and T is the post-intake time period over which dose is integrated (days).[b]

5.2.2 Composite Radionuclide Dose Commitment List

Composite listings were prepared by evaluating each radionuclide on the basis of dose delivered to its critical organ. Guidance for choice of critical organ was taken from ICRP Publication No. 2. Tables 5.3 and 5.4 are composite lists of radionuclides arranged in descending order of dose to the critical organ per μCi ingested. Ingestion pathways should be of greater long-term concern than inhalation pathways; therefore, the potential ingestion pathway should be given greater emphasis when

[b]Post-intake time period is denoted by t in Eq. (4.1), but T is used on the computer outputs because lower case letters are not used by the on-line printer.

Table 5.3. Dose to the Critical Organ of an Adult in 70 Years Following a Single Ingestion of the Soluble Form of the Radionuclide Immediately Following Detonation

No.	Radionuclide	rems/μCi	Critical Organ	No.	Radionuclide	rems/μCi	Critical Organ
1	^{90}Sr	.375(+2)[a]	Bone	14	^{89}Sr	.153	Bone
2	^{129}I	.135(+2)	Thyroid	15	^{203}Hg	.102	Kidneys
3	^{210}Pb	.117(+2)	Kidneys	16	^{140}La	.974(-1)	G.I. Tract
4	^{131}I	.252(+1)	Thyroid	17	^{125}Sn	.974(-1)	G.I. Tract
5	^{239}Pu	.122(+1)	Bone	18	^{90}Y	.974(-1)	G.I. Tract
6	^{240}Pu	.122(+1)	Bone	19	^{97}Zr	.974(-1)	G.I. Tract
7	^{238}Pu	.998	Bone	20	^{132}I	.910(-1)	Thyroid
8	^{133}I	.678	Thyroid	21	^{134}Cs	.759(-1)	Total Body
9	^{45}Ca	.452	Bone	22	^{140}Ba	.649(-1)	G.I. Tract
10	^{32}P	.222	Bone	23	^{115m}Cd	.649(-1)	G.I. Tract
11	^{135}I	.210	Thyroid	24	^{115}Cd	.649(-1)	G.I. Tract
12	^{106}Ru	.195	G.I. Tract	25	^{48}Sc	.649(-1)	G.I. Tract
13	^{144}Ce	.195	G.I. Tract	26	^{129m}Te	.649(-1)	G.I. Tract

Table 5.3., continued

No.	Radionuclide	rems/μCi	Critical Organ	No.	Radionuclide	rems/μCi	Critical Organ
27	^{132}Te	.649(-1)	G.I. Tract	41	^{59}Fe	.325(-1)	G.I. Tract
28	^{91}Y	.649(-1)	G.I. Tract	42	^{147}Nd	.325(-1)	G.I. Tract
29	^{93}Y	.649(-1)	G.I. Tract	43	^{131m}Te	.325(-1)	G.I. Tract
30	^{111}Ag	.487(-1)	G.I. Tract	44	^{92}Y	.325(-1)	G.I. Tract
31	^{143}Ce	.487(-1)	G.I. Tract	45	^{95}Zr	.325(-1)	G.I. Tract
32	^{204m}Pb	.487(-1)	G.I. Tract	46	^{91}Sr	.278(-1)	G.I. Tract
33	^{149}Pm	.487(-1)	G.I. Tract	47	^{92}Sr	.278(-1)	G.I. Tract
34	^{137}Cs	.438(-1)	Total Body	48	^{187}W	.278(-1)	G.I. Tract
35	^{134}I	.426(-1)	Thyroid	49	^{77}As	.244(-1)	G.I. Tract
36	^{198}Au	.390(-1)	G.I. Tract	50	^{152}Eu	.244(-1)	G.I. Tract
37	^{60}Co	.390(-1)	G.I. Tract	51	^{159}Gd	.244(-1)	G.I. Tract
38	^{143}Pr	.390(-1)	G.I. Tract	52	^{103}Ru	.244(-1)	G.I. Tract
39	^{127m}Te	.349(-1)	Kidneys	53	^{153}Sm	.244(-1)	G.I. Tract
40	^{207}Bi	.325(-1)	G.I. Tract	54	^{141}Ce	.216(-1)	G.I. Tract

Table 5.3., continued

No.	Radionuclide	rems/μCi	Critical Organ	No.	Radionuclide	rems/μCi	Critical Organ
55	^{115}In	.216(-1)	G.I. Tract	69	^{125m}Te	.133(-1)	Kidneys
56	^{109}Pd	.216(-1)	G.I. Tract	70	^{35}S	.132(-1)	Testes
57	^{54}Mn	.195(-1)	G.I. Tract	71	^{99}Mo	.983(-2)	Kidneys
58	^{56}Mn	.195(-1)	G.I. Tract	72	^{196}Au	.974(-2)	G.I. Tract
59	^{95}Nb	.195(-1)	G.I. Tract	73	^{155}Eu	.974(-2)	G.I. Tract
60	^{239}Np	.195(-1)	G.I. Tract	74	^{24}Na	.974(-2)	G.I. Tract
61	^{105}Rh	.195(-1)	G.I. Tract	75	^{147}Pm	.974(-2)	G.I. Tract
62	^{105}Ru	.195(-1)	G.I. Tract	76	^{36}Cl	.801(-2)	Total Body
63	^{125}Sb	.195(-1)	G.I. Tract	77	^{136}Cs	.759(-2)	Total Body
64	^{204}Tl	.195(-1)	G.I. Tract	78	^{65}Zn	.659(-2)	Total Body
65	^{185}W	.195(-1)	G.I. Tract	79	^{64}Cu	.649(-2)	G.I. Tract
66	^{22}Na	.187(-1)	Total Body	80	^{42}K	.649(2)	G.I. Tract
67	^{135}Cs	.186(-1)	Liver	81	^{149}Nd	.649(-2)	G.I. Tract
68	^{241}Pu	.178(-1)	Bone	82	^{99}Tc	.649(-2)	G.I. Tract

Table 5.3., continued

No.	Radionuclide	rems/μCi	Critical Organ	No.	Radionuclide	rems/μCi	Critical Organ
83	^{127}Te	.649(-2)	G.I. Tract	93	^{97}Nb	.216(-2)	G.I. Tract
84	^{201}Tl	.649(-2)	G.I. Tract	94	^{55}Fe	.213(-2)	Spleen
85	^{115m}In	.487(-2)	G.I. Tract	95	^{7}Be	.974(-3)	G.I. Tract
86	^{93m}Nb	.487(-2)	G.I. Tract	96	^{51}Cr	.974(-3)	G.I. Tract
87	^{203}Pb	.487(-2)	G.I. Tract	97	^{91m}Y	.649(-3)	G.I. Tract
88	^{151}Sm	.487(-2)	G.I. Tract	98	^{14}C	.573(-3)	Total Body
89	^{181}W	.487(-2)	G.I. Tract	99	^{99m}Tc	.325(-3)	G.I. Tract
90	^{87}Rb	.430(-2)	Total Body	100	^{103m}Rh	.195(-3)	G.I. Tract
91	^{129}Te	.244(-2)	G.I. Tract	101	^{3}H	.127(-3)	Total Body
92	^{93}Zr	.244(-2)	G.I. Tract				

[a]Number in parentheses indicates the exponent of 10.

Table 5.4. Dose to the Critical Organ of an Adult in 70 Years Following a Single Ingestion of the Soluble Form of the Radionuclide 60 Days Post-Detonation

No.	Radionuclide	rems/μCi	Critical Organ	No.	Radionuclide	rems/μCi	Critical Organ
1	^{90}Sr	.356(+2)[a]	Bone	14	^{60}Co	.381(-1)	G.I. Tract
2	^{129}I	.135(+2)	Thyroid	15	^{207}Bi	.320(-1)	G.I. Tract
3	^{210}Pb	.116(+2)	Kidneys	16	^{91}Y	.317(-1)	G.I. Tract
4	^{239}Pu	.122(+1)	Bone	17	^{115m}Cd	.247(-1)	G.I. Tract
5	^{240}Pu	.122(+1)	Bone	18	^{152}Eu	.241(-1)	G.I. Tract
6	^{238}Pu	.997	Bone	19	^{127m}Te	.235(-1)	Kidneys
7	^{45}Ca	.351	Bone	20	^{115}In	.216(-1)	G.I. Tract
8	^{106}Ru	.174	G.I. Tract	21	^{204}Tl	.188(-1)	G.I. Tract
9	^{144}Ce	.169	G.I. Tract	22	^{135}Cs	.186(-1)	Liver
10	^{134}Cs	.723(-1)	Total Body	23	^{125}Sb	.186(-1)	G.I. Tract
11	^{89}Sr	.670(-1)	Bone	24	^{129m}Te	.184(-1)	G.I. Tract
12	^{137}Cs	.437(-1)	Total Body	25	^{22}Na	.179(-1)	Total Body
13	^{203}Hg	.411(-1)	Kidneys	26	^{241}Pu	.177(-1)	Bone

Table 5.4., continued

No.	Radionuclide	rems/μCi	Critical Organ	No.	Radionuclide	rems/μCi	Critical Organ
27	^{54}Mn	.170(-1)	G.I. Tract	41	^{141}Ce	.590(-2)	G.I. Tract
28	^{95}Zr	.168(-1)	G.I. Tract	42	^{65}Zn	.556(-2)	Total Body
29	^{131}I	.144(-1)	Thyroid	43	^{151}Sm	.486(-2)	G.I. Tract
30	^{59}Fe	.129(-1)	G.I. Tract	44	^{93m}Nb	.482(-2)	G.I. Tract
31	^{32}P	.122(-1)	Bone	45	^{87}Rb	.430(-2)	Total Body
32	^{185}W	.111(-1)	G.I. Tract	46	^{181}W	.362(-2)	G.I. Tract
33	^{147}Pm	.931(-2)	G.I. Tract	47	^{140}Ba	.252(-2)	G.I. Tract
34	^{155}Eu	.911(-2)	G.I. Tract	48	^{93}Zr	.244(-2)	G.I. Tract
35	^{103}Ru	.883(-2)	G.I. Tract	49	^{55}Fe	.205(-2)	Spleen
36	^{35}S	.819(-2)	Testes	50	^{143}Pr	.187(-2)	G.I. Tract
37	^{36}Cl	.801(-2)	Total Body	51	^{125}Sn	.122(-2)	G.I. Tract
38	^{99}Tc	.649(-2)	G.I. Tract	52	^{147}Nd	.819(-3)	G.I. Tract
39	^{125m}Te	.649(-2)	Kidneys	53	^{14}C	.573(-3)	Total Body
40	^{95}Nb	.594(-2)	G.I. Tract	54	^{7}Be	.448(-3)	G.I. Tract

Table 5.4., continued

No.	Radionuclide	rems/μCi	Critical Organ	No.	Radionuclide	rems/μCi	Critical Organ
55	^{136}Cs	.310(-3)	Total Body	69	^{153}Sm	.149(-10)	G.I. Tract
56	^{51}Cr	.218(-3)	G.I. Tract	70	^{48}Sc	.880(-11)	G.I. Tract
57	^{111}Ag	.190(-3)	G.I. Tract	71	^{140}La	.174(-11)	G.I. Tract
58	^{3}H	.126(-3)	Total Body	72	^{77}As	.174(-12)	G.I. Tract
59	^{196}Au	.581(-5)	G.I. Tract	73	^{105}Rh	.257(-13)	G.I. Tract
60	^{132}Te	.148(-6)	G.I. Tract	74	^{143}Ce	.129(-14)	G.I. Tract
61	^{90}Y	.178(-7)	G.I. Tract	75	^{131m}Te	.116(-15)	G.I. Tract
62	^{198}Au	.799(-8)	G.I. Tract	76	^{187}W	.244(-19)	G.I. Tract
63	^{201}Tl	.621(-8)	G.I. Tract	77	^{133}I	.119(-20)	Thyroid
64	^{99}Mo	.331(-8)	Kidneys	78	^{159}Gd	.204(-25)	G.I. Tract
65	^{115}Cd	.402(-9)	G.I. Tract	79	^{97}Zr	.359(-26)	G.I. Tract
66	^{239}Np	.346(-9)	G.I. Tract	80	^{24}Na	.211(-30)	G.I. Tract
67	^{149}Pm	.302(-9)	G.I. Tract	81	^{109}Pd	.451(-33)	G.I. Tract
68	^{203}Pb	.232(-10)	G.I. Tract	82	^{64}Cu	.551(-36)	G.I. Tract

Table 5.4., continued

No.	Radionuclide	rems/μCi	Critical Organ	No.	Radionuclide	rems/μCi	Critical Organ
83	^{42}K	.122(-36)	G.I. Tract	93	^{149}Nd	0	G.I. Tract
84	^{93}Y	.657(-44)	G.I. Tract	94	^{204m}Pb	0	G.I. Tract
85	^{91}Sr	.199(-46)	G.I. Tract	95	^{103m}Rh	0	G.I. Tract
86	^{127}Te	.324(-48)	G.I. Tract	96	^{105}Ru	0	G.I. Tract
87	^{135}I	.676(-65)	Thyroid	97	^{92}Sr	0	G.I. Tract
88	^{132}I	0	Thyroid	98	^{99m}Tc	0	G.I. Tract
89	^{134}I	0	Thyroid	99	^{129}Te	0	G.I. Tract
90	^{115m}In	0	G.I. Tract	100	^{91m}Y	0	G.I. Tract
91	^{56}Mn	0	G.I. Tract	101	^{92}Y	0	G.I. Tract
92	^{97}Nb	0	G.I. Tract				

[a]Number in parentheses indicates the exponent of 10.

determining which radionuclides are to receive further study in the field. Two different cases of intake by ingestion were considered. One case assumed intake occurred immediately following detonation (no radioactive decay, Table 5.3), and the other case assumed intake occurred 60 days after detonation (after 60 days of radioactive decay, Table 5.4). An intake of 5000 µCi of each radionuclide results in a potential dose commitment of greater than 10 rems for all but seven of the radionuclides listed in Table 5.3. Radionuclides of only short-term concern are apparent from Table 5.4, since they would contribute an insignificant dose commitment if exposure started as soon as 60 days post-detonation. The zeros in Table 5.4 represent values smaller than 1×10^{-78}.

Four composite Radionuclide Dose Commitment Lists are given in Appendix X (τ = 0 and 60 days, and t = 1 and 70 years) to illustrate the effects of variations in τ and t upon the listings. Adjustment was made for the relative radiosensitivity of the various organs in the composite listings appearing in Appendix X. The following doses were assumed to have equal biological significance: 0.5 rem to the gonads, red bone marrow, or total body; 3.0 rems to the thyroid or bone, except 1.5 rems to the thyroid of children; and 1.5 rems to other single organs. For the purpose of listing, the radiosensitivity-adjusted doses were normalized to the largest value.

References for Chapter 5.0

5.1. R. A. James and E. H. Fleming, Jr., Relative Significance Index of Radionuclides for Canal Studies, UCRL-50050-1, (Sept. 13, 1966).

5.2. G. E. Raines, Battelle Memorial Institute, Communication (Oct. 5, 1966).

6.0 ENVIRONMENTAL PATHWAYS

The principal objective of the on-site canal studies is to gather environmental data that will be used to identify the pathways of radionuclide transfer to man, in order to estimate the radiation doses from radionuclides released by nuclear devices. The plan for pathway analysis presented in this section is believed to be a necessary step toward achieving these objectives. This preliminary scheme for environmental pathway analysis is based partly on the use of systems analysis techniques. Considerable interest is expressed in applying the specific activity concept to determine the concentration of particular radionuclides that can be tolerated in the biological environment. Thus, the effect of radioactive decay, biological elimination, and biological growth on the application of this concept is evaluated.

6.1 Coupled Compartment System

A useful way of dealing with environmental pathways for analytical purposes is the diagrammatic representation of the environment by a network of coupled compartments. Each compartment represents an environmental unit (e.g., grasses and herbs, surface water, sea turtles, etc.). Each has income and loss flux (via environmental pathways) which together alter the inventory of material within the compartment. The types of inventory of interest include stable element, radionuclide, and in some cases biomass. The aspect of biomass of most interest is the flux of food to man, since food is the vehicle for transfer of radionuclides and

stable elements. Amounts of food must be considered, along with activity per gram of food or per gram of element, to estimate nuclide intake in the terms needed for internal-dose models.

6.1.1 Income and Loss Model

Net flux to a compartment is the difference, income minus loss. This simple principle is illustrated below.

$$\overset{\sum_{i=0}^{n} \lambda_{ij}X_i}{\text{INCOME}} \xrightarrow{ij} \boxed{\text{COMPARTMENT } j} \xrightarrow{ji} \overset{\sum_{i=0}^{n} \lambda_{ji}X_j}{\text{LOSS}}$$

$$\frac{dX_j}{dt} = \dot{X}_j = \sum_{i=0}^{n} \lambda_{ij}X_i - \sum_{i=0}^{n} \lambda_{ji}X_j$$

The compartment of reference is designated the jth compartment which has income and loss pathways designated ij and ji, respectively. The ith compartment is designated as any compartment other than the jth compartment. For bookkeeping purposes, income always enters on the left side and loss always leaves from the right side. Income entering the compartment along pathway ij is represented by $\lambda_{ij}X_i$, where λ_{ij} is an environmental transfer coefficient having units of reciprocal days and X_i represents the stable element concentration, radionuclide concentration, or biomass in source compartment i (e.g., per unit of ground area). When there is more than one source compartment having pathways leading to compartment j, the total income is the sum of the $\lambda_{ij}X_i$ products. Likewise, the total loss for all ji pathways is the

sum of the $\lambda_{ji}X_j$ products. The difference of these two rate functions is the derivative dX_j/dt which has the units of X_i and X_j on a per-day basis (e.g., μCi m^{-2} day^{-1} for a radioactivity measurement). The complete generalized equation for this model is shown below the compartment box.

6.1.2 Environmental Transfer Coefficient

The environmental transfer coefficient, λ, is the important rate parameter which quantifies the movement of materials into and out of the various environmental compartments. Both biological and physical rate processes are included in the environmental transfer coefficient. Examples of biological rate processes include growth, metabolic elimination, and feeding, while examples of physical rate processes include meterological phenomena, transport of sediments by streams, and radioactive decay. When λ appears in the loss term of a system equation, it has the equality $\lambda = \ln 2/T = 0.693/T$, where T is the environmental half-time. For an income term, T is the environmental doubling-time. Determination of λ for loss requires an estimate of X_i at t_2, such that $X_i(t_1)/X_i(t_2) = 2$. It follows that $t_2 - t_1 = \Delta t = T$, and that λ must equal $0.693/T$. Actually, a series of measurements are taken over an appropriate time period and plots of these measurements are made on semilog paper to estimate a half-time or doubling-time from a straight line drawn through the points. Special consideration may have to be given to data that cannot be fitted with exponential equations.

Some environmental transfer coefficients will have to be determined by food-habits studies to estimate radionuclide transfer from forage to

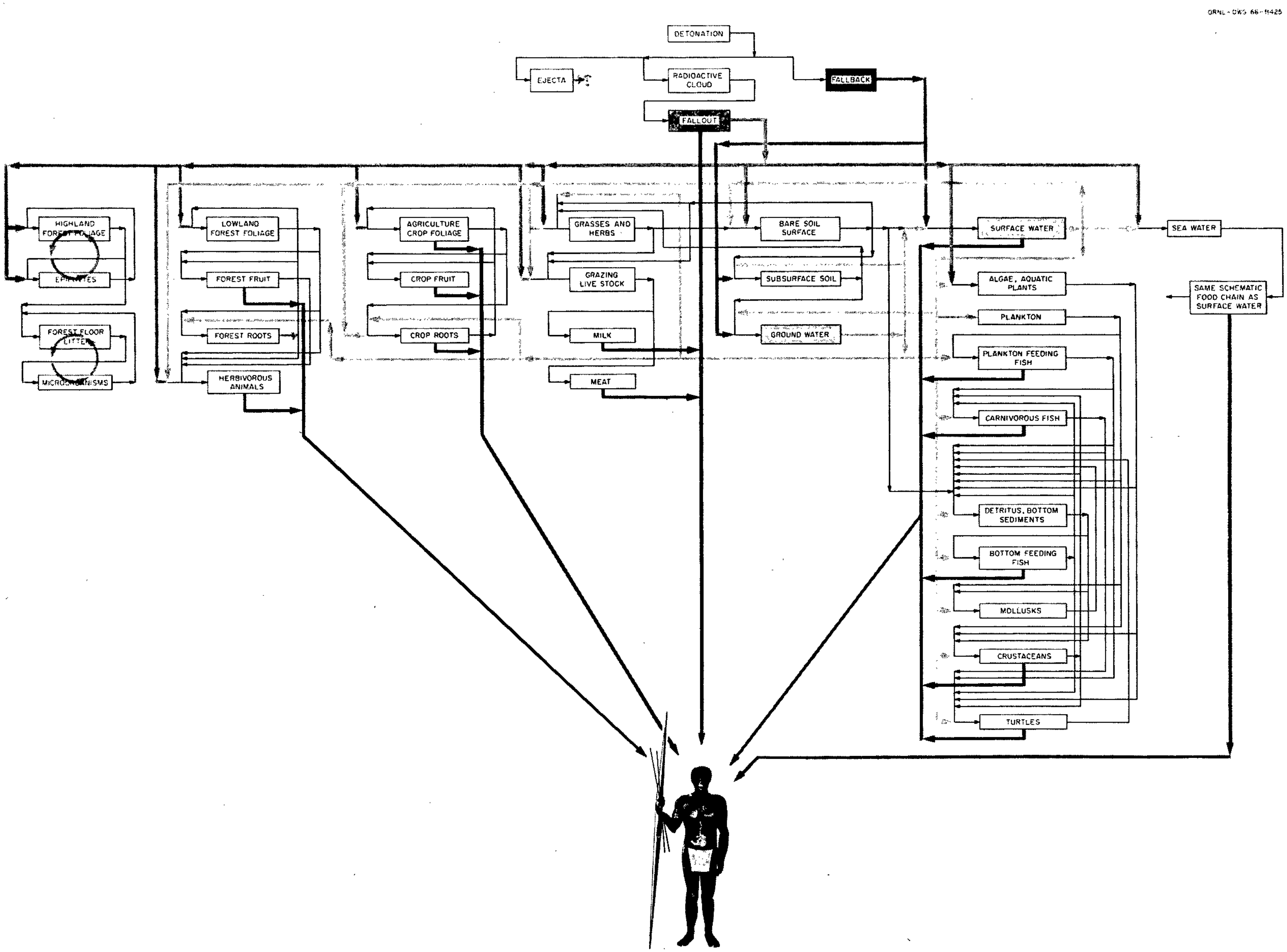

Fig. 6.1. Coupled Compartment Diagram of the Tropical Environment.

forest animals and cattle, transfer from plankton to plankton-feeding fish, transfer from plankton-feeding fish to carnivorous fish, etc.

6.1.3 Coupled Compartment Diagram of the Tropical Environment

A preliminary general diagram of a compartmental model of coupled pathways is shown in Fig. 6.1. A general purpose of the entire field program is to define the compartments, pathways, and transfer coefficients involved in the food chains leading to indigenous man. The model diagrammed in Fig. 6.1 is based only on preliminary information, and it is presented here only to illustrate the method of tracing radioactivity through the food web from point of entry to man. As pertinent data become available the model can be modified to provide a more detailed, more realistic representation of the important compartments and critical food-chain pathways. Proper implementation of this model may help to start bridging the large gap in knowledge between radioactivity entering the environment and that small fraction of the total which could contribute to the internal radiation dose received by man.

The left side of each compartment is the income side, and the right side is the loss side. Compartments that have direct food-chain inputs to man have an arrow leaving the bottom side of the compartment box.

A nuclear detonation results in a radioactive cloud, fallback material, and ejected material which is too heavy to be carried away by the cloud and is blown too far laterally to fall back into the excavation. Figure 6.1 shows only the transfer of radionuclides from fallout and fallback which comprise two source compartments for the model. This does not imply that the ejecta compartment is a sink, because it is not. Losses from the ejecta compartment have simply not been considered at

this time. The loss arrow from the fallout compartment can be followed to see where it becomes income for the primary interceptor compartments. Visualize the fallout descending on the environment and falling on forests, agricultural crops, grasses and herbs, bare soil, surface water, aquatic plants, and sea water. There may even be inhalation by livestock and man. The other source compartment, fallback, has inputs to subsurface soil, ground water, and surface water. The income to any primary receptor compartment from the two source compartments is proportioned out as loss from the primary receptor compartments to arrive as income to other compartments in the coupled system.

Forests have been arbitrarily divided into a highland ecosystem (~300 m elevation, or ecologically similar to the El Verde forest in Puerto Rico) and a lowland ecosystem (< 300 m elevation). The highland forest may be subject to runoff and possible erosion and the lowland ecosystem may accumulate water or sediments from the uplands. Recent research by Kline and Odum has shown that epiphytes on foliage were apparent accumulators of fallout radionuclides in tropical forests;[6.1] and that when radionuclide tracers (^{134}Cs, ^{85}Sr, and ^{54}Mn) were sprayed on the forest floor at El Verde, there was negligible uptake by roots.[6.2] Canopy and understory leaves in lower montane tropical forests might get many of their nutrients by aerial interception, including interception by epiphytic organisms, but chemical budget studies to determine this have been started only recently.[6.2, 6.3] The fraction of the fallout initially washed from the leaves to the forest floor in Fig. 6.1 was cycled between the forest floor microorganisms and the litter, because studies in the El Verde forest have shown that radionuclides reaching

the forest floor may not be available as income to the underlying soil and ground water.[6.2] However, a small fraction of some radionuclides may be taken up by the roots which form a thick mat in the litter layer.[6.4] Witkamp has shown that there is a high year-round activity of microorganisms in the forest floor litter at El Verde.[6.5] This observation may account for the apparent retention of some radionuclides within the forest floor ecosystem of the lower montane forest.

Provisionally, assume that the forest canopy and the forest floor litter function as ecosystem sinks, as shown by the model, and that there is no loss to compartments outside the highland forest ecosystem (e.g., by erosion of litter and soil to the lowlands). Thus, in this hypothetical situation, the fraction of the total fallout that falls in the highland ecosystem would be isolated from any direct inputs to man (unless man foraged there for food). If this ecosystem were to become a sink, it would be of significant importance because it would apply to the area of the continental divide in Panama where the elevation is about 300 m. Whether or not these broad generalizations and extrapolations between El Verde and Panama can be made remains to be determined from field observations. The first major question about the pathways diagram is whether there may be significant movement of radioactivity from the upland forests (in organic or inorganic form) to the lowland floodplains where the location of agriculture may be critical. Is it misleading to assume no such transfer, as the diagram implies?

Another feature of the diagram is the indication of the potential importance of both ground water and surface water as pathways for radioisotope transfers eventually leading to man. All major ecosystem compartments, except perhaps the highland forest ecosystem, have incomes

from surface water or ground water. The second major question, therefore, is whether ground water can be expected to carry significant quantities of radionuclides other than tritium, in view of the potential sorption of other elements in tropical soils.

The diagram has not been expanded at this time, in order to keep the preliminary model as simple as possible for illustrative reasons, and because actual field data were not available to do otherwise. Possibly some compartments should be subdivided into numerous subcompartments to provide a more realistic approximation of the environment. For example, it may be necessary to add one or more soil compartments for the crop, pasture, and forest areas, since minerals in these compartments may provide more-or-less immobilized "sinks" for many nuclides. Alternately, the root compartments (i.e., 15 and 17) may have to be pooled with soil until there is more specific information on roots and soils. In Oak Ridge forest-tagging studies, and in many fallout studies, a major question has been: How soon will critical elements be taken out of the local biogeochemical cycles and transferred into compartments with very slow turnover? This is a third major question to be answered for each of the broad ecosystems in Panama or Colombia.

In many cases it may be necessary to deal with a single large compartment measured by an average value rather than to measure the individual small compartments that make up the large compartment. For instance, it would be easier to estimate the average X_i for total plankton than it would be to estimate X_i for all individual species of plankton.

The model will be useful in a hazards analysis primarily as a guide to estimating the radionuclide burden and flux in each compartment that has loss to man via food (or water) consumed by man. The rates of

loss from the compartment of reference will be specified after each compartment is assigned a number to simplify the bookkeeping of incomes and losses. A list of 40 compartments of interest found in the preliminary diagram of environmental pathways is shown in Table 6.1. The compartment number in the left-hand column will be used to subscript the equations which describe the diagrammatic model. The source compartments are labeled 0 and 0' and they supply income directly or indirectly to compartments 1-38. The presence of an X in the right-hand column indicates that the reference compartment has a direct input to man. Twenty compartments (including fallout) have direct inputs to man.

6.1.4 Pathway Transfer Equations

All of the differential equations for this model have been written and a few are listed below to illustrate some typical forms.

Crop foliage

$$\dot{X}_3 = (\lambda_{0,3}X_0 + \lambda_{17,3}X_{17}) - (\lambda_{3,16} + \lambda_{3,17})X_3 ,$$

Crop fruit

$$\dot{X}_{16} = (\lambda_{3,16}X_3 + \lambda_{17,16}X_{17}) ,$$

Surface water

$$\dot{X}_6 = (\lambda_{0,6}X_0 + \lambda_{0',6}X_{0'} + \lambda_{5,6}X_5 + \lambda_{21,6}X_{21}) - (\lambda_{6,7} + \lambda_{6,11}$$

$$+ \lambda_{6,22} + \lambda_{6,23} + \lambda_{6,24} + \lambda_{6,25} + \lambda_{6,26} + \lambda_{6,27} + \lambda_{6,28} + \lambda_{6,29}$$

$$+ \lambda_{6,5} + \lambda_{6,4} + \lambda_{6,10} + \lambda_{6,17} + \lambda_{6,9})X_6 ,$$

Freshwater plankton-feeding fish

$$\dot{X}_{23} = (\lambda_{6,23}X_6 + \lambda_{22,23}X_{22}) - (\lambda_{23,24} + \lambda_{23,25} + \lambda_{23,29})X_{23} ,$$

Table 6.1. Listing of Compartments for Preliminary Environmental Pathways Diagram

Compartment No.	Compartment Identification	Direct Input to Man
0	Fallout	X
0'	Fallback	
1	Highland Forest Foliage	
2	Lowland Forest Foliage	
3	Agricultural Crop Foliage	X
4	Grasses and Herbs	
5	Bare Soil Surface	
6	Surface Water	X
7	Sea Water	
8	Highland Forest Epiphytes	
9	Herbivorous Forest Animals	X
10	Grazing Livestock	X
11	Fresh-Water Algae, Aquatic Plants	
12	Highland Forest Floor Litter	
13	Highland Forest Floor Microorganisms	
14	Lowland Forest Fruit	X
15	Lowland Forest Roots	
16	Crop Fruit	X
17	Crop Roots	X
18	Livestock Milk	X
19	Livestock Meat	X
20	Subsurface Soil	
21	Ground Water	
22	Fresh-Water Plankton	
23	Fresh-Water Plankton-Feeding Fish	X
24	Fresh-Water Carnivorous Fish	X
25	Fresh-Water Detritus, Bottom Sediments	
26	Fresh-Water Bottom-Feeding Fish	X
27	Fresh-Water Mollusks	X
28	Fresh-Water Crustaceans	X
29	Fresh-Water Turtles	X
30	Salt-Water Algae, Plants	
31	Salt-Water Plankton	
32	Salt-Water Plankton-Feeding Fish	X
33	Salt-Water Carnivorous Fish	X
34	Salt-Water Detritus, Bottom Sediments	
35	Salt-Water Bottom-Feeding Fish	X
36	Salt-Water Mollusks	X
37	Salt-Water Crustaceans	X
38	Salt-Water Turtles	X

Sea turtles

$$\dot{X}_{38} = (\lambda_{7,38}X_7 + \lambda_{33,38}X_{33} + \lambda_{32,38}X_{32} + \lambda_{35,38}X_{35} + \lambda_{30,38}X_{30} + \lambda_{37,38}X_{37}) - (\lambda_{38,34}X_{38}).$$

In the first differential equation the subscript 3 refers to the compartment known as agricultural crop foliage. The net flux (μCi m^{-2} day^{-1}) in compartment 3 is designated $\dot{X}_3$. Income to compartment 3 comes from fallout (compartment 0) and crop roots (compartment 17), while losses are to crop fruit (compartment 16) and crop roots (compartment 17). Losses to the soil surface or herbivorous animals are not shown here, but may need to be added to remove the unrealistic simplifying assumption that man consumes all of the crops that he grows. The equation for crop fruit is an interesting example, because it shows crop fruit to be a sink which has no losses to other compartments (loss to man is not considered here). Thus, the fourth major question, or complex of questions, concerns the typical and extreme amounts of production of crops per unit area, activity per unit weight (fresh and dry), and the amounts or fractions of this total which actually enter the digestive tract after wasted and discarded production are taken into account. Some of these numbers are available now (or can be assumed with reasonable accuracy), and others will be provided by field investigations now in progress.

In summary, it is not the preliminary diagram that is the blueprint for studying the pathways problem; rather a systems analysis approach based on an income-and-loss model is recommended. This approach can be used because it is possible to determine environmental transfer coefficients.[6.4, 6.6]

6.2 Specific Activity Concept

Reference is frequently made to the specific activity concept as a method for evaluating the hazard to man from radionuclides in the environment. Some assumptions for applying various specific activity models are: (1) stable and radioactive atoms of the element are completely mixed and behave similarly, (2) biological half-time is known, (3) organisms are in equilibrium with their environment, (4) concentrations of the stable element are known, (5) rates of growth of the organisms are known, and (6) rates of input of radioactive atoms are constant. An important limitation of any specific activity model is that it relates only to a single radionuclide and does not give guidance on the cumulative radiation dose to all organs of the body. However, a reasonable level below which a radionuclide may be disregarded may become apparent from the ranking of radionuclides.

Probably the most serious threat to validity of the use of specific activities lies in ignoring important parameters and requirements in simplification of the concept. The following discussion will show graphically the relative importance of the parameters (i.e., physical half-life, biological half-time, biological growth, and time) in a specific activity model when certain constants are specified. This treatment is intended to elucidate under what conditions certain data must be obtained, and under what conditions certain data might not be necessary for specific activity calculations.

6.2.1 Simple Two-Compartment Model

Consider a two-compartment model with the following notation:

X_i = concentration of radioisotope (atoms/g) or number of atoms in compartment i (i = 1, 2),

Y_i = concentration of stable element (atoms/g) or number of atoms of element in compartment i, and

$S_i = X_i/(X_i + Y_i)$ = specific activity (dimensionless) in compartment i.

For convenience, let compartment 1 represent sea water and compartment 2 represent a critical organ of man. If there is no isotopic discrimination or radioactive decay, then the specific activity anywhere along a food chain is constant, and the specific activities at opposite ends of a food chain are equal. Furthermore, if instantaneous equilibrium is assumed for the stable and radioactive atoms of the same element between the two compartments, then

$$\frac{X_1}{X_1 + Y_1} = \frac{X_2}{X_2 + Y_2}\text{, or } S_1 = S_2 \tag{6.1}$$

The assumption of instantaneous equilibrium means that losses by physical decay and biological elimination are balanced by growth and intake.

6.2.2 Generalized Model

Since the conditions outlined under the simple two-compartment model are unlikely in many cases, the simple model should be expanded so that [6.7]

$$\frac{X_1}{X_1 + Y_1} = \frac{X_2}{X_2 + Y_2}\left[\frac{\lambda_r + \lambda_b + \lambda_g}{\lambda_b + \lambda_g}\right]\left[\frac{1}{1-e^{-(\lambda_r + \lambda_b + \lambda_g)t}}\right], \tag{6.2}$$

where

λ_r = radioactive decay constant (days^{-1}),

λ_b = biological elimination constant for critical organ of man (days^{-1}),

λ_g = growth constant for critical organ of man (days^{-1}), and

t = time (days).

The constants λ_r and λ_b represent the fractional loss of X_2 by physical decay, and the fractional loss of $X_2 + Y_2$ by biological elimination, respectively. Further definition of the rate constants gives $\lambda_r = \ln 2/T_r$, and $\lambda_b = \ln 2/T_b$. T_r and T_b are the physical half-life (days) and biological half-time (days), respectively. If growth rate is assumed to be exponential, then the mass W(g) of the critical organ may be represented by $dW/dt = \lambda_g W$, which gives $W(t) = W_o e^{\lambda_g t}$ when $W = W_o$ at $t = 0$. Doubling can be represented by $W = 2W_o = W_o e^{\lambda_g t}$. Let $t = T_g$, the doubling time (days). This gives $\lambda_g = \ln 2/T_g$ for the doubling-time constant for growth of the critical organ in man. Thus, $W(t) = W_o e^{(0.693/T_g)t}$.

In most environmental situations there is negligible mass of the radioisotope. Making this assumption for Eq. (6.2), and setting X_1 and X_2 in the denominator equal to zero, yields

$$X_1 = \frac{X_2}{Y_2} Y_1 \left[\frac{\lambda_r + \lambda_b + \lambda_g}{\lambda_b + \lambda_g} \right] \left[\frac{1}{1-e^{-(\lambda_r + \lambda_b + \lambda_g)t}} \right] . \qquad (6.3)$$

For use of specific activities in environmental hazard analysis, X_2 can be redefined as the concentration of the radioisotope in the critical organ that will deliver the maximum permissible dose (i.e., maximum

permissible burden of the radionuclide in critical organ divided by mass of the critical organ). As a result, S_1 becomes the concentration of the radioisotope in sea water which, if maintained at a constant level, will induce a concentration in the critical organ which delivers the maximum permissible dose to man.

6.2.3 Sensitivity Analysis of Parameters

Consider the first bracketed quantity in Eq. (6.3). For analytical purposes let

$$F = \frac{\lambda_r + \lambda_b + \lambda_g}{\lambda_b + \lambda_g} = \frac{\frac{T_b T_g}{T_r} + T_g + T_b}{T_g + T_b} , \qquad (6.4)$$

and assume the second bracketed quantity in Eq. (6.3) equals one because t is large. A given radionuclide has the same λ_r in any biological system. On the other hand, λ_b is a constant for a given radioisotope (or stable element) in a specified biological system or organ. Further assume, $\lambda_g = 0$ because there is no growth, then $F = F'$ (a special case of F) = $(\lambda_r + \lambda_b)/\lambda_b = 1 + T_b/T_r$. Provided the ratio T_b/T_r is constant, F' is independent of the absolute values of T_b and T_r and can be evaluated easily as shown in Fig. 6.2. The selected range of T_b/T_r goes from 0.1 to 10, while F' has a corresponding range of from 1.1 to 11. This range of F' is the range of conservativeness that would correspond to use of the simple model ($S_1 = S_2$) as compared to $S_1 = S_2F'$. Conservativeness, as used here, refers to the difference between the value of X_1 calculated from the simplest model ($S_1 = S_2$), and the value of X_1 calculated from some other model.

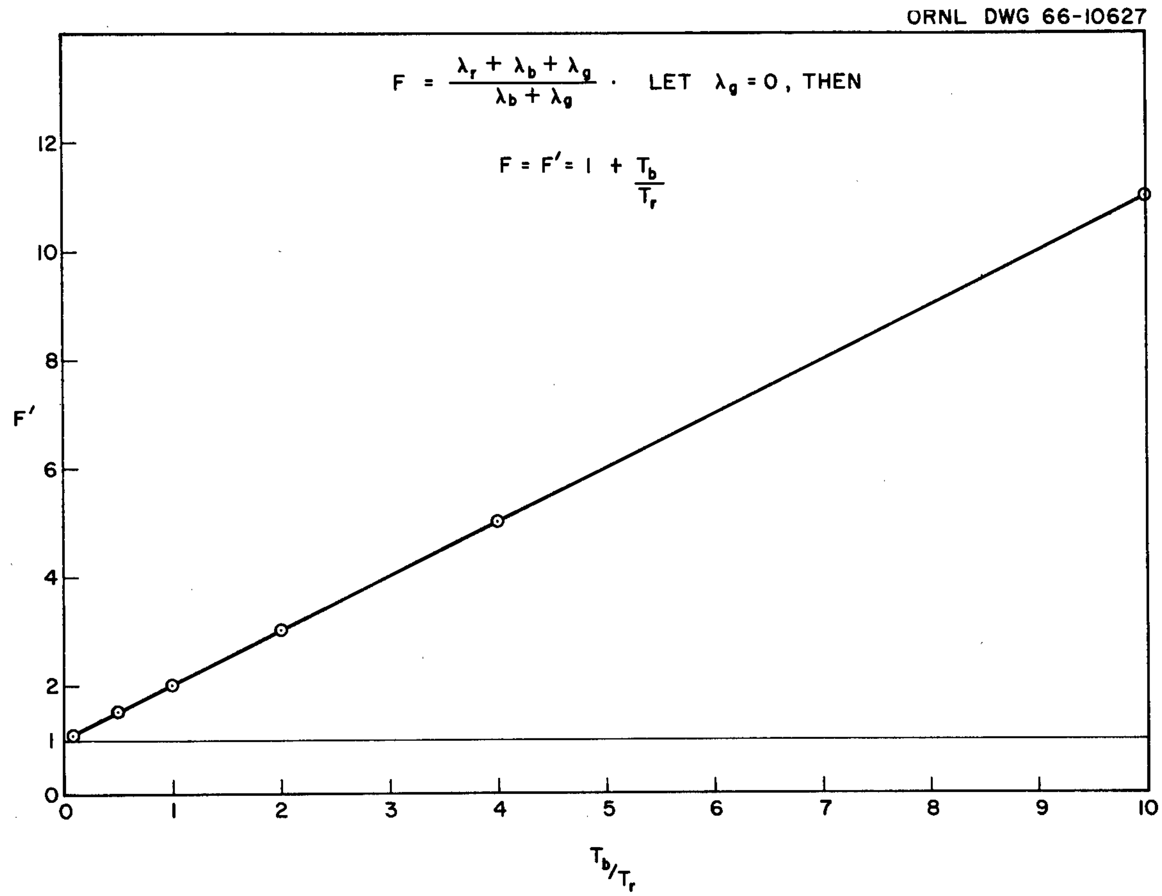

Fig. 6.2. Plot of F' as a Function of T_b/T_r.

In the case of a growing organism, the rate of growth must be considered. This case of F is given by Eq. (6.4). The result of plotting F as a function of T_g for three different ratios of T_b/T_r(0.1, 1, and 10) is shown in Fig. 6.3. The shape of each curve depends upon the value of T_b chosen to calculate F. Variation of a particular value of F does not exceed 10% for a wide range of T_b(1 to 10,000 days) where T_b/T_r is held constant. Figure 6.3 shows that, in all cases, neglect of using F in the calculation of maximum permissible concentration would result in conservative estimates. These estimates become more conservative as T_b/T_r and T_g increase.

If the exponential term in Eq. (6.3) is set equal to E and T_b/T_r and T_g are specified, then the relation (F × E) vs. t can be plotted where

$$E = \left[\frac{1}{1 - e^{-(\lambda_r + \lambda_b + \lambda_g)t}}\right] .$$

Figure 6.4 is a graph for the conditions $T_b/T_r = 0.1$ and $T_b = 100$ days. This graph shows the range of conservativeness that would correspond to use of the simple model ($S_1 = S_2$) when the doubling-time is long and t < 100 days. The next figure (Fig. 6.5) for $T_b/T_r = 1$ yields plots that are essentially the same as in the previous graph which specified that $T_b/T_r = 0.1$. The significant difference comes in the next figure (Fig. 6.6) which applies to a ratio of $T_b/T_r = 10$. This ratio would be relevant approximately to ^{185}W, ^{181}W, ^{45}Ca, ^{89}Sr, and ^{91}Y in bone of man. The conservativeness factors (F × E) for the simple model ($S_1 = S_2$) when t $\geq$ 100 days are: 2 for $T_g = 10$, 6 for $T_g = 100$, and 10 for $T_g \geq 1000$. Another way of stating the results of this graph is to

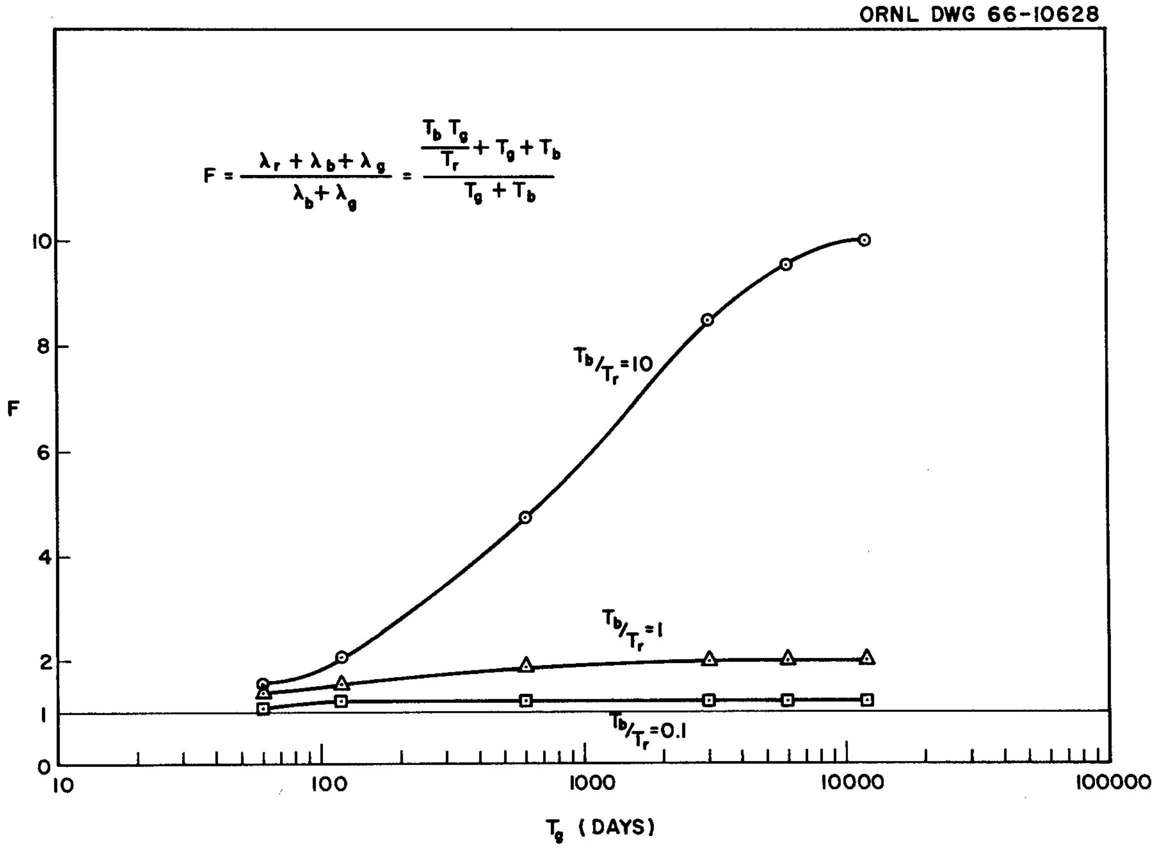

Fig. 6.3. Plot of F as a Function of T_g for Three Different Ratios of T_b/T_r(0.1, 1, and 10).

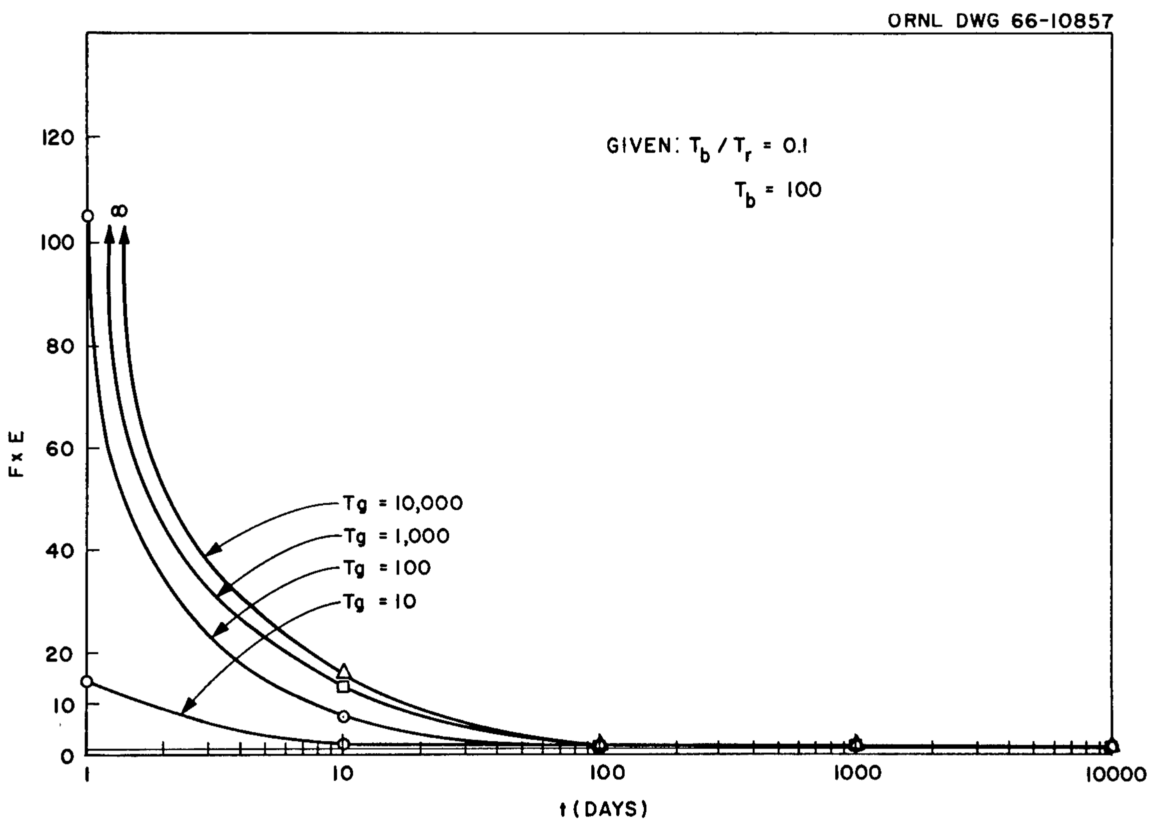

Fig. 6.4. Plot of (F X E) as a Function of Time for $T_b/T_r = 0.1$, T_b = 100 Days, and T_g Ranging from 10 to 10,000 Days.

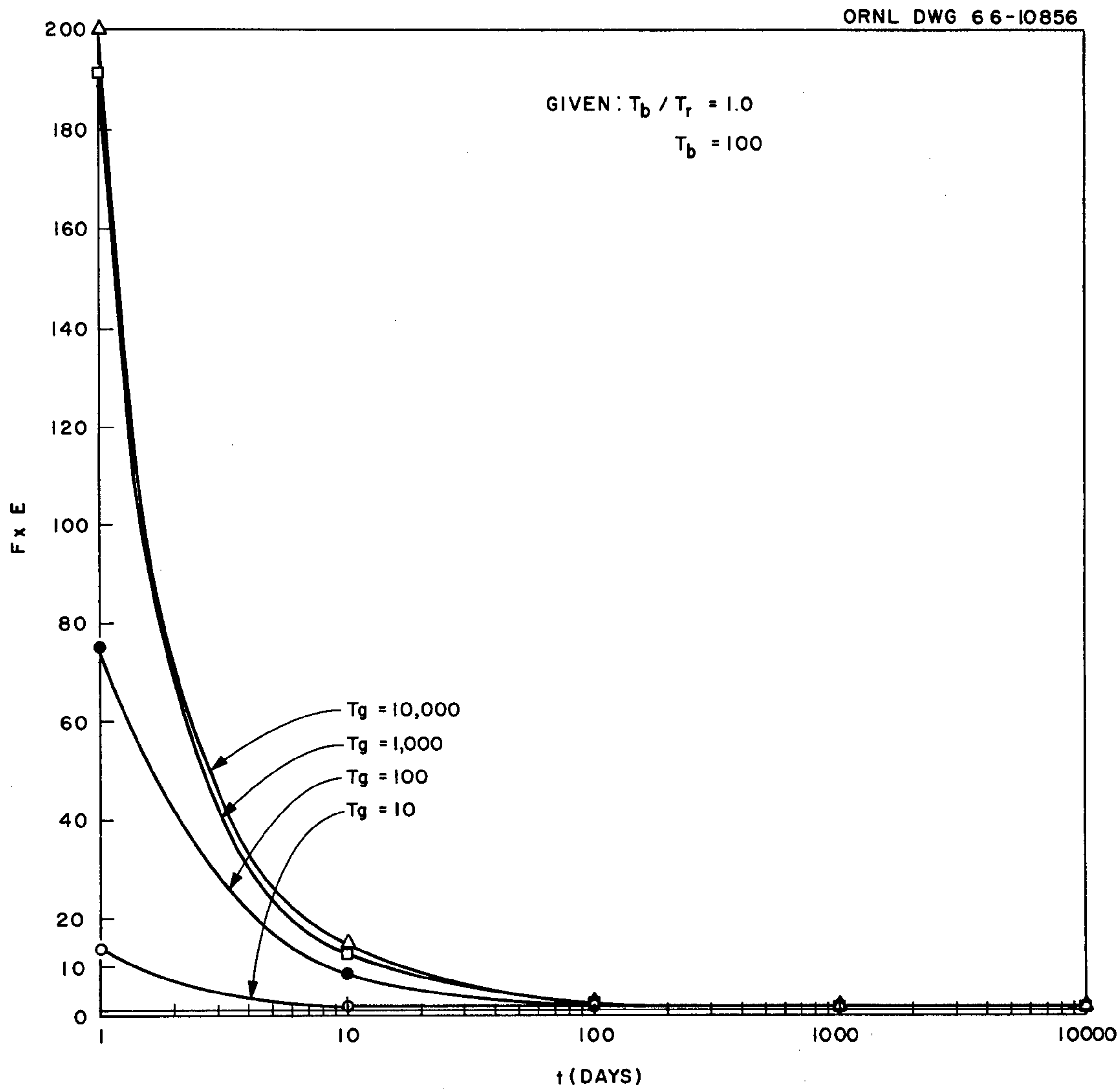

Fig. 6.5. Plot of (F X E) as a Function of Time for $T_b/T_r = 1$, T_b = 100 Days, and T_g Ranging from 10 to 10,000 Days.

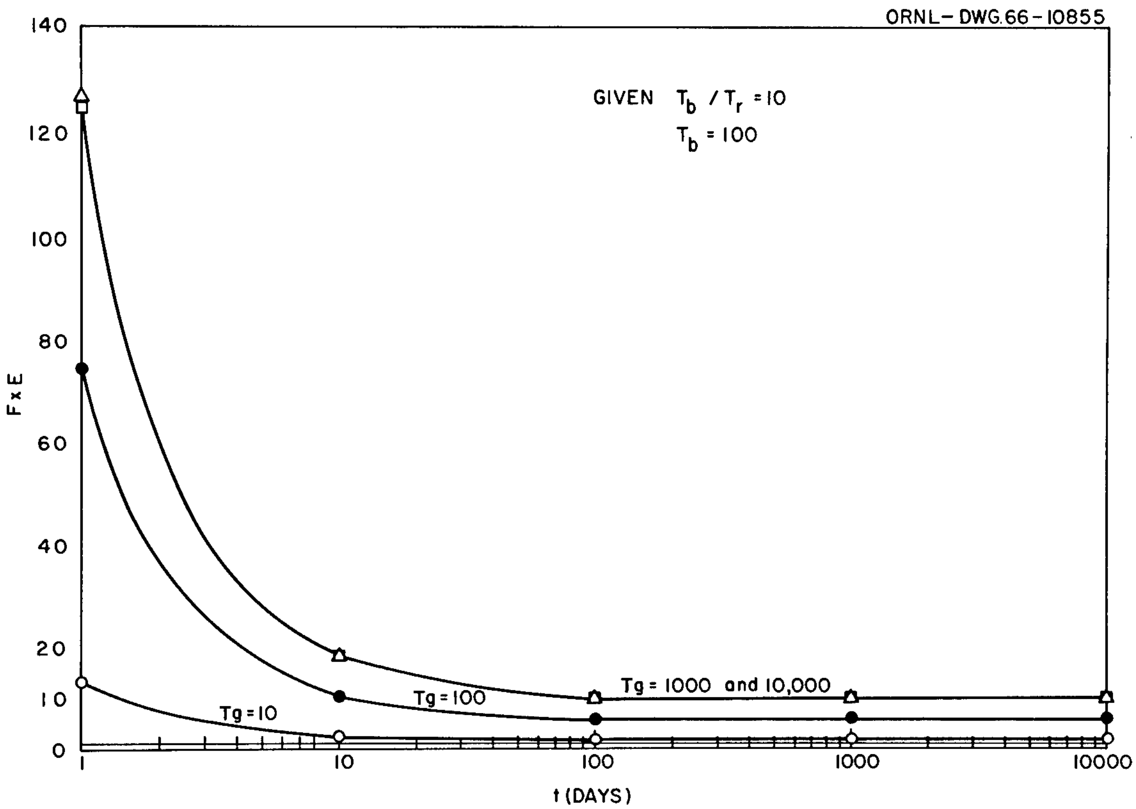

Fig. 6.6. Plot of (F × E) as a Function of Time for T_b/T_r = 10, T_b = 100 Days, and T_g Ranging from 10 to 10,000 Days.

say that the generalized model ($S_1 = S_2 \times F \times E$) allows up to ten times more radioactivity to be released into the environment than the simple model allows. This order of magnitude conservativeness might actually be very conservative itself, if the food-chain steps between sea water and the critical organ of man are considered. The following hypothetical food chain may be used as an example:

$$\left.\begin{array}{ll} S_{(\text{sea water})} & = S_{(\text{plankton})} \\ S_{(\text{plankton})} & = S_{(\text{herring})} \\ S_{(\text{herring})} & = S_{(\text{tuna})} \\ S_{(\text{tuna})} & = S_{(\text{critical organ of man})} \end{array}\right\} \Longrightarrow S_{(\text{sea water})} = S_{(\text{critical organ of man})}$$

Up to this point it has been assumed that the food-chain steps could be neglected and specific activity in sea water could be related to specific activity in the critical organ of man. Since every food-chain step on the left side of the bracket will have an $(F \times E) = 1$ or ≥ 1, the product of all the $(F \times E)$ values should be computed. The result is likely to be greater than a value computed by directly relating the specific activity of sea water to the specific activity in the critical organ of man. The Working Group of the Committee on Oceanography of the National Academy of Sciences - National Research Council has stated that "The use of only one such factor is conservative by the product of those neglected."[6.7] In most cases, the simple model will furnish a very conservative estimate of the concentration of radioactivity that can be allowed in the environment; however, realistic values require the use of the more generalized model. Use of the generalized model requires biological information which may be hard to get, so the simple model may have to

be used out of necessity. Certainly, there should not be a significant hazard from a particular radionuclide if the predicted concentration of this radionuclide in sea water is much lower than the maximum concentration permitted for sea water as calculated by the simple model ($S_1 = S_2$). It may even be possible to exceed the maximum concentration permitted for sea water, if the condition is only a transient condition, as contrasted to continuous input specified in the models used thus far. For a single release resulting in concentrations above MPC values, the minimum rate of loss from the environment will equal the radioactive decay rate, so that when all loss processes are operative, the maximum permissible dose over a given period may not be exceeded for some situations.

Since complete mixing of released radionuclides and their stable analogues may take years in some cases, the utility of the specific activity concept may be seriously impaired during the time when it would be needed most. This situation may be true especially for certain terrestrial habitats where mixing may be slowest.

References for Chapter 6.0

6.1. J. R. Kline and H. T. Odum, Bulletin of the Ecol. Soc. of Amer. 47, 121 (1966).

6.2. J. R. Kline, Bulletin of the Ecol. Soc. of Amer. 47, 119 (1966).

6.3. M. Witkamp, "Mineral Retention by Epiphyllic Organisms," in A Tropical Rainforest, in manuscript.

6.4. J. R. Kline, "Retention of Fallout Radionuclides of Stratospheric Origin by Tropical Forest Vegetation," in A Tropical Rainforest, in manuscript.

6.5. M. Witkamp, "Aspects of Soil Microflora in a Gamma Irradiated Rainforest," in A Tropical Rainforest, in manuscript.

6.6. W. E. Martin, Health Phys. 11, 1341 (1965).

6.7. National Academy of Sciences - National Research Council, Disposal of Low-Level Radioactive Waste into Pacific Coastal Waters, Publ. 985 (1962).

7.0 RADIATION SAFETY CRITERIA

One of the principal objectives of the Bioenvironmental and Radiological Safety Feasibility Study is to compare the estimated external and internal dose rates and total doses to individuals and/or population groups in the affected areas with existing guidelines established by recognized authorities.[7.1] The hazard of significant exposure situations must be assessed in the context of these guidelines. The reports of recognized authorities considered in this study include those by the International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA), the National Council on Radiation Protection and Measurements (NCRP), the Federal Radiation Council (FRC), and the British Medical Research Council (MRC).

7.1 Dealing with Radiation Protection Problems in Terms of Risk

Criteria providing guidance for radiation safety are considered in the context of three different situations: (1) where there is effective control of the radiation source (e.g., reactors and reactor fuel processing plants); (2) where the release of radiation or radioactive contamination to the environment is inevitable even though the source is under reasonable control (e.g., use of nuclear explosives for peaceful purposes); and (3) where the source is not under control (e.g., reactor accidents). In all three situations, the decision to take certain action involves a balancing of alternatives.

In the first two cases, there is a balancing of the benefits obtained by carrying out the operation against the risks entailed by the radiation exposure, as well as other, more conventional risks. Radiation risk is not essentially different from other types of risk (e.g., the hazards of occupational disease, electric shock, explosions, falls, and fires). Radiation risks, however, often require a different emphasis because (1) man's senses do not warn him of his exposure and people are not generally aware of the nature of the hazard as is the case with explosions and fires, and (2) in some situations, particularly in the construction of a sea-level canal with nuclear explosives, the persons exposed will include not only those working on the project — and hence subject to supervision and monitoring — but also many persons not directly involved with the project. While both (1) and (2) apply, to some extent, to the more conventional hazards of industry, their impact in the case of radiation exposure is vastly greater. For this reason, the planning of operations involving radiation exposure is generally more detailed and the criteria limiting the exposure are needed and used as a basis for such planning.

In the case of emergency exposure, one is confronted with an existing situation, and the source of radiation is not effectively under control. The concept of the balancing of benefits and risks is still operative, but the question is one of balancing alternatives. The exposure is in progress and can be terminated or mitigated only by remedial actions which, in themselves, may involve considerable risks.

The risks entailed by radiation exposure at high levels of dose are well known and do not require documentation. Much less is known

about exposure at lower levels and there is almost no direct evidence of damage at, say, the levels of permissible occupational exposure. These levels have been arrived at, over the last forty years, through a general lowering of exposure criteria due (1) to experience in the nuclear industry which showed that lower levels could be met at a reasonable cost, and (2) to accumulating evidence which tended to indicate the presence of effects at the higher levels. For example, an increased incidence of bone cancer in persons with a residual bone burden of 1 μg or more of ^{226}Ra can be considered as practically demonstrated.[7.2] The evidence also supports a decrease in life span, an increased incidence of leukemia among radiologists during the last 40 years,[7.3] and some risk of lung tumors among uranium miners.[7.4] The exposure levels in these cases range an order of magnitude or more above the present occupational levels, but usually not as much as two orders of magnitude above these levels. In all cases, the incidence of effects is statistical in nature so that not all those exposed at a given level show the effect. Thus, one must deal with radiation exposure problems in terms of risk.

As indicated above, there is little direct evidence on which to base an estimate of risk at exposure levels equal to or below the permissible occupational exposure limits. If a threshold for incidence of a particular effect existed, and if an operation could be carried out below this threshold level, then the risk of that particular effect would be zero. However, no such threshold limits of dose have been demonstrated for the more important effects of concern (e.g., malignancies, life shortening, and genetic effects). On *a priori* grounds, it would be extremely difficult to demonstrate the existence of a threshold by direct

observation for, even though no effects are observed in an exposed group of a certain size, this may only indicate that the incidence is low. Faced with this difficulty, the ICRP, IAEA, NCRP, FRC, and MRC have all assumed the "linear hypothesis" (i.e., that risk is, to a first approximation, proportional to dose). This assumption is believed to be, if not accurate, on the conservative side in that most dose-effect curves are linear or concave upward so far as they have been determined at relatively low doses.

The "linear hypothesis" and "no threshold" assumptions also imply that there is some risk, however small, involved in any exposure to ionizing radiation. Thus, all the above mentioned authorities declare the policy that no unnecessary exposure is justified or, equivalently, that all operations should be carried out so as to minimize exposures as far as practicable. Therefore, any operator has the obligation to minimize exposures below permissible occupational and/or population levels when this can be done without significantly impeding the operation.

Exposures above these permissible levels require more scrutiny and evaluation to insure that the benefits accruing from the operation justify the additional exposures. The FRC[7.5] has stated, "Federal agencies should apply these Radiation Protection Guides with judgment and discretion, to assure that reasonable probability is achieved in the attainment of the desired goal of protecting man from the undesirable effects of radiation. The Guides may be exceeded only after the Federal agency having jurisdiction over the matter has carefully considered the reason for doing so in light of the recommendations in this staff report." In testimony before a special committee of the Joint Congressional Committee

on Atomic Energy,[7.6] the chairman of the FRC indicated that the FRC would expect to be aware of and, perhaps, review such cases. Thus, if higher levels of exposure are to be experienced in construction of the sea-level canal with nuclear explosives, the Interoceanic Canal Commission should be prepared to offer a formal justification.

7.2 Current Guidelines for Radiation Safety

On the bases sketchily outlined above, guidelines for occupational exposure and for exposure of members of the population have been given by the five authorities. While there are considerable differences in the details of their respective recommendations, no doubt due, in part, to differences in the publication dates of their most recent recommendations. the basic limits of exposure are virtually identical. These are recommendations by all the agencies for "normal peace-time operations." Implicit in their selection is the judgment that the benefits normally accruing to individuals and to society from the normal conduct of business is sufficient justification to balance the low level of risk these values are considered to entail.

7.2.1 Permissible Limits of Exposure for Occupational Workers

The present maximum permissible doses (MPD) recommended by the ICRP, IAEA, NCRP, and FRC for occupational exposure are shown in Table 7.1.[7.7, 7.8] These MPD values are applied to both internal and external exposures. The formula for accumulated dose, $5(N - 18)$, where N is the

Table 7.1. Recommended Maximum Permissible Dose Equivalents for Occupational Workers

Organ	Maximum Dose Equivalent (rem) in 13 Weeks	Maximum Permissible Dose Equivalent (rem) in 1 Year	Accumulated Dose Equivalent (rem)
Red Bone Marrow	3 — I,A,N,F	5 — I, A,N	5(N-18) — I,A,N,F
Total Body	3 — I,A,N,F	5 — I,A,N	5(N-18) — I,A N,F
Head and Trunk	3 — N,F	5 — N	5(N-18) — N,F
Gonads	3 — I,A,N,F	5 — I,A,N	5(N-18) — I,A,N,F
Lenses of Eyes	3 — A,N,F 8 — I	5 — A,N,F 15 — I	5(N-18) — I,A,N,F
Skin	8 — A,N 10 — F 15 — I	30 — I,N,F, 32 — A*	
Thyroid	8 — A,N 10 — F 15 — I	30 — I,N,F 32 — A*	
Bone	8 — A 10 — F* 15 — I	30 — I,N 32 — A*	
Hands, Forearms Feet and Ankles	20 — A,N 25 — F 38 — I	75 — I,N,F 80 — A*	
All Other Organs	4 — A 5 — F 8 — I	15 — I,N,F 16 — A*	

F = FRC; FRC identifies its values as Radiation Protection Guides (RPG)

A = IAEA

N = NCRP

I = ICRP

* = Implied

individual's age in years, is intended to provide some flexibility in occupational exposure situations when the need arises. Considering the 13-week permissible exposures (Column 2) where the formula applies, it is seen that 12 rems could be accumulated in one year. However, all five authorities emphasize that workers who have accumulated a dose higher than that permitted by the formula should not be exposed at a rate higher than 5 rems/year until the accumulated dose is lower than that permitted by the formula. The formula implies that occupational exposures should not be permitted for individuals whose age is less than 18 years. However, in countries where this occupational age restriction is not limiting, the ICRP[7.9] and the IAEA[7.10] recommend that exposures to the whole body, gonads, blood-forming organs, and lenses of the eyes should not exceed 5 rems in any one year; and the accumulated dose at age 30 should not exceed 60 rems.

For the application of these occupational MPD values to internal exposures, the ICRP[7.11, 7.12] and the NCRP[7.13] have calculated permissible body burdens and maximum permissible concentrations of radionuclides in air and water that are as consistent as possible with these age-proration and MPD limits. The MPD limits used for this purpose are those listed in Table 7.1, Column 3, and entitled "Maximum Permissible Dose Equivalent (rem) in 1 Year." For bone-seeking radionuclides, as an example, the permissible bone burden is based on the deposition of the radionuclide in bone, the relative biological effectiveness of the radiation involved, and a comparison of the effective energy release in the bone with the effective energy release from a bone burden of 0.1 μg of ^{226}Ra plus daughters. This permissible bone burden corresponds to approximately 30 rems per year. Once the bone burden has been estimated,

calculations are made as to the daily intake which, continued over a 50-year period, would not result in an accumulation greater than the permissible bone burden. The basis of these calculations for exposures via ingestion and inhalation is the so-called "standard man" which provides representative constants for the many variables involved. After the permissible daily intake has been determined, maximum permissible concentrations in air and water (MPC_a and MPC_w) are derived by assuming that the daily intake of air and water are uniformly contaminated. These give MPC values for the 168-hour week which are then adjusted upward to allow for the shorter time exposure involved in a 40-hour week.

7.2.2 Permissible Levels of Exposure for Members of the Population-at-Large

The present annual dose levels recommended by the ICRP, IAEA, NCRP, and FRC for members of the general population are listed in Table 7.2. With but one exception (see footnotes "d" and "e"), the values listed are 1/10 of the maximum permissible dose equivalents permitted in one year for occupational workers (see Column 3 of Table 7.1).[7.14, 7.15] It is seen that the FRC does not have Radiation Protection Guides (RPG) for some organs. However, in his Memorandum for the President,[7.16] the chairman of the FRC recommended that "where no Radiation Protection Guides are provided, Federal agencies continue present practices." This is taken by these authors to mean that the dose levels (and concentration guides) to be followed by Federal agencies in such cases should be those recommended by the ICRP and NCRP. Thus, there appear to be no important differences among the recommendations of these authorities concerning permissible exposure levels for members of the general population.

Table 7.2. Annual Dose Levels for Members of the Public

Organ or Tissue	NCRP[a]	FRC[b]	ICRP	IAEA
Gonads, Red Bone Marrow	0.5 rem	0.5 rem[c]	0.5 rem	0.5 rem
Total Body	0.5 rem	0.5 rem[c]	0.5 rem	0.5 rem
Lenses of the Eyes	0.5 rem		0.5 rem	0.5 rem
Other Single Organs	1.5 rems		1.5 rems	1.5 rems
Skin, Bone, Thyroid	3 rems	1.5 rems[d]	3 rems[e]	3 rems
Hands, Forearms, Feet, Ankles	7.5 rems		7.5 rems	7.5 rems

[a]These levels are based on NCRP's simple recommendation that the permissible dose to members of the population at large be reduced to not more than 1/10 of the occupational values.

[b]The FRC dose not recommend Radiation Protection Guides for individual organ doses to the population other than gonads and whole body.

[c]The FRC specifies that the RPG for gonads shall be 5 rems in 30 years for average population groups on the assumption that the majority of individuals do not vary from the average by a factor greater than 3; thus, the permissible annual dose to gonads and whole body for average population groups would be 0.17 rems.

[d]The FRC recommends RPG's for the thyroid of 1.5 rems/yr for individual and 0.5 rem/yr to be applied to the average of suitable samples of an exposed group in the population.

[e]The ICRP recommends 1.5 rems/yr to the thyroid of children up to 16 years of age.

There are a number of reasons why permissible dose levels for members of the general population should be less than those for occupational workers. Most important among them is the consideration of population genetics which makes it desirable to limit exposure of the gonads of the whole population. Another important reason is the fact that infants and children are not included in the highly-selected, homogeneous, occupationally exposed groups. It follows then, that the 1/10 safety factor and additional safety factors are usually applied in situations involving exposure of members of the general population.

All recognized authorities define a genetic dose, on the bases of the "linear hypothesis" and "no threshold" assumptions, that is relevant to an assessment of the genetic burden or genetic risk to the whole population. Specifically, they recommend that the genetic dose to the general population from all radiation sources, excluding natural background and medical sources, should not exceed 5 rems in the interval from conception to the mean age of childbearing (30 years). They suggest, further, that the annual genetically significant dose should be the average of the individual gonad doses, each weighted by the expected number of children to be conceived after the exposure. To determine an average genetic dose for a whole population, then, it is necessary to measure or estimate not only the doses to individual members, but also to know the number of individuals exposed. Any determination or estimation of the annual genetically significant dose, in addition, requires information on the demography of the population affected.

No specific recommendations are made by these authorities as to a permissible, somatically-significant dose for members of the general

population. In cases of external exposure of the whole body to penetrating radiation, however, the limitation imposed by the genetic dose discussed above, by itself, reduces the doses to internal organs to or below the annual levels listed in Table 7.2. The same applies to internal exposure resulting from radionuclides which contribute to the gonadal dose of a population. In cases of internal exposure resulting from radionuclides or mixtures of radionuclides which concentrate in organs other than the gonads, it is suggested that the concentrations of such radionuclides in air or water should not exceed 1/30 of the MPC values for continuous occupational exposure. In situations where it it possible to identify the critical population group (i.e., the group expected to receive the highest dose), the ICRP[7.17] indicates it may be appropriate to use the 1/10 reduction factor instead.

7.3 Assessment of Risks to a Population from Environmental Contamination

The FRC[7.18, 7.19, 7.20, 7.21, 7.22] and the MRC[7.23, 7.24, 7.25] have considered the consequences of the release of radioactive materials to the environment resulting from (1) industrial accidents involving reactors and nuclear fuel reprocessing plants, and (2) releases of radioactive materials from the detonation of nuclear weapons or nuclear devices. The recommendations of the FRC and the MRC provide additional guidance concerning action levels which may be applied in this radiological-safety feasibility study.

7.3.1 FRC Recommendations

Table 7.3 summarizes the Protective Action Guides (PAG) recommended by the FRC in respect to (1) planning protective actions to reduce potential doses to the population from radioactive materials which may gain access to food, and (2) doses at which implementation of protective actions may be appropriate. It is seen that the radionuclides of interest include ^{137}Cs, $^{89,90}Sr$, and ^{131}I, and that PAG's for three categories are given, except in the case of ^{131}I. This exception is made because ^{131}I will have disappeared a few weeks after the contaminating event. The PAG's for Category I are about equal to the annual doses regarded as permissible ones for those occupationally exposed to radiation (see Column 3 of Table 7.1). The PAG's for Category II are 1/2 those for Category I, and those for Category III are the same as the annual dose levels regarded as permissible ones for members of the general population (Table 7.2). The FRC suggests, as an operational technique, that the PAG will be met if the average absorbed dose to a suitable sample of the exposed population is 1/3 the PAG or approximately 3 rads for Category I, 2 rads for Category II, and 0.2 rads for Category III.

7.3.2 MRC Recommendations

The MRC recommendations are for maximum permissible daily intakes of four radionuclides (viz., ^{131}I, $^{89,90}Sr$, and ^{137}Cs) which might be of the greatest importance during an accident, and in the period following it, in determining the suitability of food for consumption or air for breathing. The maximum intakes of ^{131}I for various ages correspond to a total thyroid irradiation of 25 rads, as compared with a maximum annual

Table 7.3. FRC Protective Action Guides for the Acute Contaminating Event

Radionuclide	PAG's for Category I[a]	PAG's for Category II[b]	PAC's for Category III[c]
^{137}Cs	10 rads in first year to bone marrow or whole body of individual; 3 rads to average of suitable sample; total dose must not exceed 15 rads.	5 rads in first year to bone marrow or whole body of individual; 2 rads to average of suitable sample.	0.5 rads in first year to bone marrow of individual; 0.2 rads to average of suitable sample.
^{89}Sr	Same as above	Same as above	Same as above
^{90}Sr	Same as above	Same as above	Same as above
^{131}I	30 rads in first year to thyroid of individual; 10 rads to average of suitable sample (considered to consist of children of 1 year of age).	See Paragraph 7.3.1	See Paragraph 7.3.1

[a]Category I is concerned with immediate transmission of radionuclides through the pasture-cow-milk-man pathway. PAG is stated in terms of a projected dose that might otherwise be received if protective action is not taken. Protective action must be initiated in about 1 week to be effective in averting most of the potential intake.

[b]Category II is concerned with the transmission of radionuclides to man through dietary pathways other than that specified in Category I during the first year following an acute contaminating event. Immediate protective action to reduce the potential intake will not usually be required because of the normal delay in the use of food crops or animal feed crops.

[c]Category III is primarily concerned with the long-term transmission of ^{90}Sr through soil into plants in the years following a contaminating event. Any protective action that may be taken must be based on the long-term reduction of radionuclide concentrations in products grown in the contaminated area.

value of 30 rads for occupational exposures. The intakes for ^{89}Sr and ^{90}Sr correspond to a total of 15 rads and an annual rate of 1.5 rads per year, respectively, at sites of highest concentration in bone, as compared with an occupational rate of 15 rads per year in bone.[7.23] The ^{137}Cs intake gives a total dose of 10 rads to the whole body, which is less than the maximum annual occupational value of 12 rads for whole-body external irradiation, but greater than the average annual value of 5 rads.[7.23]

Table 7.4 summarizes, for a convenient comparison, the action levels of both the FRC and the MRC.[7.8] Again, it is seen that the recommended values are essentially identical.

7.4 Proposed Criteria[a] for Assessment of Possible Radiation Risks Involved in Canal Construction with Nuclear Explosives

Since the principle of balancing benefits and risks applies in the present case, the Interoceanic Canal Commission should evaluate the exposure situations and the limitations on construction operations that further limitations of dose will entail. It is only on the basis of such an evaluation that a final selection of acceptable levels in excess of those commonly used can be justified. Nevertheless, some guidance can perhaps be offered in terms of radiation safety criteria that have been used and that might reasonably apply in an operation of this scope and magnitude. For convenience, the proposed criteria are summarized in Table 7.5.

---

[a]This term is adopted to avoid any confusion with terms used by recognized authorities to designate their official guides.

Table 7.4. FRC Protective Action Guides[a] and Comparable Values Recommended by a Committee of the UK Medical Research Council[b]

Radionuclide	Protective Action Guides (PAG) Projected Absorbed Doses[c] and Critical Organs[d] During First Year to Individual (rad)	During First Year to Sample (rad)	During 70 Years to Individual (rad)	During 70 Years to Sample (rad)	Permissible Total Intakes to Individual (μ Ci)	Permissible Total Intakes to Sample (μ Ci)
^{137}Cs	10W,M (10)W	3W,M	10W,M (10)W	3W,M	77 (6,15,115)	26
^{89}Sr	1M (15)B	3M	10W,M (15)B	3W,M	100	33
^{90}Sr	3M[e] (1.5)B	1M[e]	15W,M	5W,M	5	1.7
^{131}I	30T (25)T	10T	30T (25)T	10T	1.8 (0.65,1.2,3.4,15)	0.6

[a]Protective Action Guides, as presented in FRC Reports No. 5 and No. 7, were developed for use as guidance in situations involving the rapid transmission of radionuclides from pasture to milk to man (Category I).

[b]The values given in parentheses are those recommended by the UK Medical Research Council's Committee on Protection Against Ionizing Radiation (British Medical Journal, April 11, 1959, vol. i, pp. 967–969). The values given for ^{137}Cs of (6,15,115) refer to intakes by children at birth, children at six months and adults over 20 years of age, respectively; the values given for ^{131}I of (0.65, 1.2, 3.4, 15) refer to intakes by children up to six months, children at three years, children at 10 years and adults over 20 years of age, respectively.

[c]Values of projected absorbed dose during the first year and during 70 years are for the critical segment of the population following intake of the radionuclide for 100 days by the pasture to milk to man pathway.

[d]Organs for which the projected absorbed doses are calculated include: W = whole body; B = Bone; M = Red Bone Marrow; and T = Thyroid.

[e]These values are implied by FRC's general statement (Report No. 7, page 3) that "the total dose from ^{90}Sr is assumed to be 5 times the dose in the first year."

Table 7.5. Radiation Safety Criteria for the Bioenvironmental and Radiological-Safety Feasibility Study

Critical Organs	Currently Accepted Dose Limits or Dose Commitments for Individuals in the General Population Requiring No Special Evaluation[a] rems/year	Projected Dose Commitments Requiring Special Evaluation of Risks vs Benefits[b]	
		Maximum Dose Commitment in Any One Year Following the Contaminating Events[c] rems/year	Maximum Dose Commitment in Seventy Years Following the Contaminating Events[d] rems/70 years
Red Bone Marrow	0.5	3	10
Gonads	0.5	3	10
Whole Body	0.5	3	10
Lenses of Eyes	0.5	8	15
Other Single Organs	1.5	8	15
Skin, Bone, Thyroid[e]	3.0	15	30
Hands, Forearms, Feet, and Ankles	7.5	38	75

[a]Values listed are from ICRP, FRC, and IAEA, and are for individuals in the general population. They should be reduced to 1/3 these numerical values when applied to the average of a critical group in the population. These dose limits, or dose commitments, are permissible for the lifetime of an individual in the general population without undue risk. Any situation leading to exposure in excess of these limits should be evaluated appropriately and efforts should be made to reduce them accordingly.

[b]Considering all exposure situations judged to be important in the construction of Routes 17 and 25 with nuclear explosives, dose commitments will be estimated (projected) for each radionuclide and each exposure pathway (as a function of time following each contaminating event and distance from the two canal alignments) for several different age groups in the contiguous populations, and summed. If the estimated dose commitments exceed the levels in column 2, special considerations (including cost estimates) will be required to assess the feasibility of methods to reduce the potential exposures, balancing the benefits against the risks. Generally, the higher the projected dose commitments, the greater will be the effort required to reduce potential exposures.

[c]Maximum dose commitment for any one year is the estimated (projected) dose which would be received in one year for individuals in the general population from the contaminating events if no action were taken to avert it.

[d]Maximum dose commitment in 70 years is the estimated lifetime dose which would be received by individuals in the general population from the contaminating events if no action were taken to avert it.

[e]ICRP and FRC recommend that the annual dose for the thyroid gland of children be limited to 1.5 rems.

7.4.1 Dose Commitments Requiring No Special Evaluation

Dose limits or dose commitments in this category are listed in Column 2 of Table 7.5. They are the annual doses currently regarded as maximum permissible ones for members of the general population by all the recognized authorities (see Table 7.2). The footnote "a" specifies the manner in which they should be regarded and applied. Exposure at or below these levels is considered to entail a low level of risk.

7.4.2 Dose Commitments Requiring Special Evaluation

Higher levels are given in Columns 3 and 4 of Table 7.5. These values represent levels which seem reasonable for the proposed operation provided it can be shown that at substantially lower levels the operation would be significantly impeded or become impracticable.

The values in Column 3 are essentially those entailed by 6 months of exposure at the permissible occupational limits (see Column 3 of Table 7.1). While they are acceptable for occupational exposure, this does not, in itself, endorse their use for exposure of members of the population.[7.26] In proposing these values for this application, if higher levels must be used, it is recognized that exposures at these rates should not be allowed to continue over many years. Therefore, Column 4 is added which, in effect, limits the total dose from this operation that members of the population may receive. In interpreting these values in terms of risk, it should be remembered that not all members of the population will receive the same dose. This may be due to a wide variety of causes such as age, sex, personal habits, mode of life, and physiological differences.

Also, some allowance must be made for increased radiosensitivity of some elements of the population, especially fetuses and children. These values have been selected after taking these factors into account and thus represent values which, in the judgment of these authors, might be considered to apply to all members of the affected population.

The values recommended in Column 4 may be compared with recommendations of the FRC and the MRC (Tables 7.3 and 7.4). These authorities recommended the use of 30 rems and 25 rems, respectively, as guides for the exposure of the thyroid. The critical individual was considered to be the infant of 1 to 2 years of age, and the evaluation took into account the additional sensitivity of the thyroid of a child, as compared to that of an adult.

The evidence concerning radiosensitivity was discussed in FRC reports[7.14, 7.20] and was considered extensively in a report by the NAS-NRC.[7.27] Evidence concerning critical individuals of populations, so far as exposure to $^{89,90}Sr$ and ^{137}Cs is concerned, was cited by the FRC[7.22] and more particularly by a NAS-NRC committee[7.28] appointed by the FRC for that purpose. The FRC then adopted a PAG of a mean dose of 10 rads to bone marrow or whole body of individuals in the general population, and further provided that the total dose not exceed 15 rads.

In its 1959 report,[7.23] the MRC recommended a limit of 1.5 rads per year at the site of highest concentration in bone as a criterion of exposure to members of the general population, with a limitation on total dose of 15 rads. If account is taken of the fact that the rem, as used in Table 7.5, is considered to be the rem as defined by ICRP and, hence, includes a modifying factor of 5 for exposure of the bone to beta radiation, it will be recognized that the values given by the MRC are

considerably higher than those recommended in Table 7.5. However, the values given in Table 7.5 are expressed in terms of an average over the entire skeleton where the MRC values are maximum at the sites of highest concentration in bone. Thus, the disparity is much less than appears from the numerical values.

It should be understood that in proposing the use of the values given in Columns 3 and 4 of Table 7.5 as criteria for this particular operation, the proposed values are justified only if it is found that the operation would be seriously hampered and impeded by attempting to carry out the operation at lower levels of exposure. The principle remains that unnecessary exposure is to be avoided, and that the use of exposure levels beyond those considered to be justified in the normal course of business and industrial operations involves the responsibility of determining, with some degree of care, that the additional margin of exposure is, in fact, necessary to the practical conduct of the operation. This can only be established by considering how the operation would proceed if attempts were made to carry it out at a series of exposure levels somewhat lower than those suggested here. The planning should provide for some estimates of cost what would be encountered if lower levels were used, so that it can be established and documented that exposures above the current permissible levels of population exposure are, in fact, required for successful completion of the operation. It is assumed that such studies will be made, and the criteria recommended here are for use only if it is found that lower levels would pose serious difficulties in completing the project. On the other hand, if it is found that lower levels would be a serious impediment, it is believed that the importance of this project is sufficient to justify the use of the higher levels.

This judgment is based on a comparison with the situations considered by the FRC and the MRC in recommending their levels. Inevitably, a certain element of judgment is involved here, but the successful development of a sea-level canal through the Isthmus appears to be a contribution of such magnitude to the national life and welfare that the use of exposure levels comparable to those recommended by the FRC and the MRC for use in local situations following weapons tests or reactor incidents are certainly justified. At the same time, it is with reluctance that one would envisage the possibility that doses might substantially exceed these levels, say by a factor of 2 or more. In that case the doses might approach levels comparable to those where effects have been observed. For example, in the case of children irradiated with X-rays for benign enlargements of the thymus gland, the estimated dose at which some malignancies were produced ranged as low as 100 R.[7.27] Admittedly, these estimates were not very precise and there is the possibility of a number of other factors being involved. Nevertheless, it would be disturbing if exposures to the thyroids of children were to come substantially close to 100 rads. Similarly, it would not seem wise to allow the bone marrow of fetuses or infants to be exposed at levels substantially in excess of those suggested here, say by a factor of 2 or 3. It is believed that any substantial increase in these levels would require formidable justification and a much more detailed evaluation of the potential biological effects.

References for Chapter 7.0

7.1. Battelle Memorial Institute (Columbus), Bioenvironmental and Radiological-Safety Feasibility Studies, Atlantic-Pacific Interoceanic Canal, p. 1-1, (Jan. 13, 1967).

7.2. R. D. Evans, Health Phys. (In press).

7.3. Shields Warren, Health Phys. 12, 737 (1966).

7.4. R. Seltzer, AMA Arch. of Env. Health 10, 923 (1965).

7.5. Federal Radiation Council, Background Material for the Development of Radiation Protection Standards, Report No. 1, p. 38, para. 7.13, U. S. Govt. Ptg. Off., Wash., D.C. (May 13, 1960).

7.6. Hearing before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, 86th Congress, Second Session on Radiation Protection Criteria and Standards; Their Basis and Use, May 24, 25, 26, 31, June 1, 2, and 3, 1960, U. S. Govt. Ptg. Off., Wash., D.C. (1960).

7.7. International Atomic Energy Agency, Basic Safety Standards for Radiation Protection, Safety Ser. Publ. 9, p. 9, Vienna (1962).

7.8. K. Z. Morgan, "Present Status of Recommendations of the ICRP, NCRP and FRC," presented at the Health Phys. Soc. Meeting in Los Angeles, June 14, 1965; to be publ. in Prog. in Nuclear Energy Ser. XII, vol. 2. Pergamon Press, London.

7.9. International Commission on Radiological Protection, Recommendations of the International Commission on Radiological Protection (Adopted Sept. 17, 1965), ICRP Publ. 9, p. 11, para. (61), Pergamon Press, London (1966).

7.10. International Atomic Energy Agency, Basic Safety Standards for Radiation Protection, Safety Ser. Publ. 9, p. 17, para. 3.1.5, Vienna (1962).

7.11. International Commission on Radiological Protection, Recommendations of the International Commission on Radiological Protection (Report of Committee 2 on Permissible Dose for Internal Radiation), ICRP Publ. 2, Pergamon Press, London (1959).

7.12. International Commission on Radiological Protection, Recommendations of the International Commission on Radiological Protection (As Amended 1959 and Revised 1962), ICRP Publ. 6, Pergamon Press, London (1964).

7.13. National Committee on Radiation Protection, Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure, N.B.S. Handbook 69 and Addenda, U.S. Govt. Ptg. Off., Wash., D.C. (June 1959).

7.14. Federal Radiation Council, Background Material for the Development of Radiation Protection Standards, Report No. 2, p.9, para. 2.9, U.S. Govt. Ptg. Off., Wash., D.C. (Sept. 1961).

7.15. International Commission on Radiological Protection, Recommendations of the International Commission on Radiological Protection (Adopted Sept. 17, 1965), ICRP Publ. 9, p. 13, para. (73), Pergamon Press, London (1966).

7.16. A. S. Flemming, "Radiation Protection Guidance for Federal Agencies," in Federal Register, p. 4402 (May 18, 1960).

7.17. International Commission on Radiological Protection, Principles of Environmental Monitoring Related to the Handling of Radioactive

Materials (Rpt. of Com. 4) ICRP Publ. 7, Pergamon Press, London (1966).

7.18. Federal Radiation Council, Health Implications of Fallout from Nuclear Weapons Testing through 1961, Report No. 3, U.S. Govt. Ptg. Off., Wash., D.C. (May 1962).

7.19. Federal Radiation Council, Estimates and Evaluation of Fallout in the United States from Nuclear Weapons Testing Conducted through 1962, Report No. 4, U.S. Govt. Ptg. Off., Wash., D.C. (May 1963).

7.20. Federal Radiation Council, Background Material for the Development of Radiation Protection Standards, Report No. 5, U.S. Govt. Ptg. Off., Wash. D.C. (July 1964).

7.21. Federal Radiation Council, Revised Fallout Estimates for 1964-1965 and Verification of the 1963 Predictions, Report No. 6, U.S. Govt. Ptg. Off., Wash., D.C. (Oct. 1964)

7.22. Federal Radiation Council, Background Material for the Development of Radiation Protection Standards (Protective Action Guides for Strontium-89, Strontium-90 and Cesium-137), Report No. 7, U.S. Govt. Ptg. Off., Wash. D. C. (May 1965).

7.23. British Medical Research Council, Brit. Med. J. i, 967 (1959).

7.24. British Medical Research Council, Brit. Med. J. ii,576 (1961).

7.25. British Medical Research Council, The Assessment of the Possible Radiation Risks to the Population from Environmental Contamination, A Report to the Medical Research Council by their Committee on Protection Against Ionizing Radiation, Her Majesty's Stationery Office, London (1966).

7.26. Federal Radiation Council, Background Material for the Development of Radiation Protection Standards, Report No. 1, p. 30, para. 5.20, U.S. Govt. Ptg. Off., Wash. D. C. (May 1960).

7.27. National Academy of Sciences, Pathological Effects of Thyroid Irradiation, Report of a Panel of Experts from the Committees on the Biological Effects of Atomic Radiation, NAS-NRC, Published by the Federal Radiation Council (July 1962).

7.28. National Academy of Sciences, The Effects on Man from Irradiation by Internally Deposited Strontium-89, Strontium-90 and Cesium-137, A NAS-NRC Report to the Federal Radiation Council (1964).

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Critical Radionuclides

A search of the literature has provided external and internal dose models (see Chapters 3.0 and 4.0) for the modes of exposure considered to be important. These models were used to develop Radionuclide Dose Commitment Lists (see Appendixes III through X). The position of a radionuclide in the lists does not necessarily indicate importance, or lack of importance, to the feasibility study since radionuclides cannot be ranked in terms of their hazard potential without including information on production, venting, and environmental exposure pathways. Thus, development of the Radionuclide Dose Commitment Lists is but the first of four steps (see Chapter 5.0) which should lead to a more realistic identification of radionuclides likely to be critical in canal construction. The second step includes the incorporation of production and venting estimates into the calculations. Steps three and four should consider adjustments based on fallout predictions and adjustments for redistribution of the vented and nonvented radionuclides. These final two steps can best be taken by conjoint effort among those in the study familiar with nuclear explosives, with fallout predictions, with behavior of radionuclides in the environment, and with dose estimation techniques.

The internal dose models require input information describing the habits and characteristics of the population under consideration (see Appendix I). All calculations to date have employed data drawn from Caucasian populations. Information in current literature describing

the populations living in the vicinity of the proposed excavation routes is inadequate for internal dose estimation purposes. The internal dose models can be used effectively only if other subcontractors to this study supply the information needed to complete Table 4.1, describing the adult segments of the populations. The internal dose model [Eq. (4.1)] has been shown to contain several parameters which are age-dependent; therefore, calculation of dose commitment to a population requires separate consideration for each age group. If the age-dependent parameters are not evaluated for the populations of the canal area, an alternative method will have to be used to estimate dose commitment to the younger segments of the populations, because the ultimate determination of radiological-safety feasibility must be based on dose estimates made for the critical age groups. One possibility would be to evaluate the age-dependent factor for the Caucasian population (for whom some data are available) and apply it to the dose estimate calculated for the adult segments of the populations under consideration. The transfer of an age-dependency factor assumes the net effect of age upon internal dose to be the same for both populations. The variations in the ratios in Table 4.1 indicate these parameters are characteristic of each definable population. However, when specific information from a given population is not available, it is recommended that the modification factors developed for the Caucasian population be used as the first approximation.

8.2 Environmental Pathways

The final predictions of the pathway terms in the general dose models [see Eqs. (2.1) and (2.2)] can be made with a systems analysis approach based upon a coupled compartment model (see Fig. 6.1). The model should be based on functional environmental units (populations, communities, or ecosystems) since the requisite data can most easily be obtained on these bases. One of the basic inputs to this model would be the output of the fallout prediction program (e.g., $\mu Ci/cm^2$ for a specified location). Each radionuclide would have to be treated separately, as would the season of the year in relation to rainfall. Many other factors may need special attention also, but this approach still seems reasonable since the model could be programmed for a large digital computer.

The environmental transfer coefficients for compartment income and loss of radioactivity are among the major unknowns that have to be determined before the model can be used to analyze environmental pathways. Although it is possible to estimate the transfer of radioactivity from one compartment to another, the complexity of the tropical ecosystems will make it difficult to obtain data required to make the model operational.

Field investigations will have to give special consideration to hydrology, because all compartments in the proposed pathways diagram (see Fig. 6.1) have direct inputs from either ground water or surface water. A possible exception is the highland forest ecosystem, diagrammed without such inputs. Since preliminary field research indicates that the epiphytic growths in nondeciduous, tropical highland forests may

accumulate fallout radionuclides over periods of years, the possibility of ecosystem sinks for radionuclides must be explored further by more comprehensive field studies. These studies should also include the effect of particle size on foliar retention, possibly by field use of fallout simulants which can be produced with specified particle size, solubility, radioisotope, and specific activity.

Initial calculations with the pathways model should be made using information from the literature, and the voids can be estimated by upper and lower bounds. Computer simulation of the model is recommended to provide solutions of simultaneous differential equations which will at least provide a sensitivity analysis indicating which of the transfer coefficients have a large impact on the dose estimated for man. This sensitivity analysis should help guide further field efforts toward improving certain estimates where it is most important to do so, and replacing some of the estimated numbers with empirical values where it is possible for this to be done.

The type of environmental measurements required for the systems model is similar to the type required for the specific activity approach of evaluating possible hazardous situations following the proposed nuclear excavations. The systems approach, and specific activity approach, when carried out concurrently, will supply comparative results and tend to strengthen the overall evaluation of the pathway term in the dose estimation models.

The specific activity concept may be useful for the marine environment, and possibly for parts of the fresh water environment. At present, application of this concept to the terrestrial environment is likely to

be limited, principally because there may not be uniform mixing of radioactive atoms with stable atoms of the same element. The concentration of a radionuclide allowed in the environment by the simplified specific activity model is always conservative, compared to the generalized specific activity model which considers biological elimination, radioactive decay, and biological growth (see Fig. 6.6). Thus, when the assumptions for application of the simplified specific activity model are met, this model is recommended for use in the feasibility study because it requires a minimum of analytical data and the guidance it provides is conservative.

8.3 Radiation Safety Criteria

Levels of permissible exposure for members of the general population, as currently recommended by five national and international authorities (i.e., ICRP, IAEA, NCRP, FRC, and MRC) for what are termed "normal peace-time operations", are virtually identical (see Table 7.2).

These currently accepted guidelines for exposure of a population are considered to entail a low level of risk when balanced against the benefits normally accruing to individuals and to society from the conduct of normal peace-time nuclear operations. They may be applied in the present case if it is found that the construction of a sea-level canal with nuclear explosives would not be seriously hampered or impeded.

Higher levels of population exposure, (see Table 7.5) based on a comparison of the canal situation with situations considered by the FRC and the MRC in recommending certain protective action levels (see

Table 7.4), may be justified only if it is found that the canal operation would be seriously hampered or impeded by carrying out the operation at the lower, currently accepted levels of population exposure.

Since the principle of balancing benefits and risks applies in the present case, the Interoceanic Canal Commission will have to evaluate the exposure situations and the limitations on construction operations that further limitations of dose will entail. It is only on the basis of such an evaluation that a final selection of acceptable exposure levels in excess of those commonly used can be justified. Planning of the operation, therefore, should provide for some estimates of cost that would be encountered if lower levels were used, so that it can be established and documented that exposures above the currently accepted levels are, in fact, required for successful completion of the operation.

APPENDIX I

Data Requirements for Dose Estimation Study

1. Construction Details for Rt 17 and Rt 25

Engineering Plans

size and location of nuclear explosives and sequence detonations

current plans for exclusion zones

current plans for population relocation

current plans for time of reentry

canal details (size, angle of repose, etc.)

Source Term

quantity of radionuclides produced (fission, fusion, activation)

fraction of radionuclides vented

original distribution of vented radionuclides (cloud, land surface, water surface)

fractionation

original distribution of nonvented radionuclides

chemical and physical character of vented and nonvented radionuclides

2. Native Population

Demography

density

population census by location

house location and construction

sex and age distribution

birth rate

child-bearing age

APPENDIX I, continued

Dietary Habits (by location)

water sources and intake rates (by age and sex)

food sources, types, and intake rates (by age and sex)

food preparation

breast feeding

Physical Characteristics (by location)

Domestic Habits

3. Land and Water Use (by location)

Drinking Water

Agriculture

Livestock

Recreation

Natural Resources

Freshwater and Marine Harvests

Accessibility (land, water, air)

4. Geology and Geophysics

Stratigraphy

Permeability

Porosity

Inhomogeneities

Thermal Properties

Earthquake History

5. Ground Water

Water Table Contours

Water Level Fluctuations

APPENDIX I, continued

Rate and Direction of Flow

Height of Capillary Fringe

Artesian Conditions

Areas of Recharge and Discharge

Chemical Composition

Physical Characteristics

6. Surface Water (fresh and saline)

Rate of Flow

Flow Pattern

Sediment Concentration and Composition

Chemical Composition

Physical Characteristics

Water Characteristics (flooding, intrusion)

7. Climate and Meteorology

Rainfall

- annual mean
- range
- distribution
- intensity

Wind

- direction
- velocity
- distribution

Temperature

- annual mean

APPENDIX I, continued

range

distribution

Stability

Evaporation

8. Soil

Infiltration Rate or Permeability

Moisture Content

Bulk Density

Porosity

Particle Size

Chemical Composition

Mineral Composition

Distribution Coefficients

Chelating Properties

Redox Potential

9. Plants (terrestrial and aquatic by species)

Productivity

Land or Water Surface Coverage

Evapotranspiration

Life Cycle Period

Rate of Decomposition

Soil or Nutrient Media to Crop Transfer Coefficients

Foliar Contamination Potential

Rate or Percent of Translocation

Effective Half-Life

Chemical Composition (Specific Activity)

Plants Consumed

APPENDIX I, continued

10. Animals (of food value)

    Productivity

    Product Contamination

    Chemical Composition (Specific Activity)

    Parts Consumed

11. Insects (of food value)

    Amounts Available

    Chemical Composition (Specific Activity)

    Parts Consumed

12. Maps and Photos

    Topography

    Geology

    Stratigraphy

    Ground Water Hydrology

        water table

        depth to water

    Surface Water Hydrology

        flow patterns

        bottom contours

    Accessibility

        roads

        paths

        waterways

        airstrips

APPENDIX I, continued

Soils

    type

    depth

Habitation

Land and Water Use

    agriculture

    livestock

    fishing

    natural resources

Vegetation

Canal Location and Features

Land and Water Deposition of Radionuclides

APPENDIX II

NUCLEAR PROPERTIES OF RADIONUCLIDES[a]

Nuclide	Half-life	Decay Constant λ(sec-1)	Yield (%)	Beta Particles: Fraction f_1	Beta Particles: E_o(Mev)	Beta Particles: $\bar{E}$(Mev)	Gamma Transition: Fraction f_2	Gamma Transition: E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
Ge^{78}_{32}	86 min	1.34×10^{-4}	1.8×10^{-2}	1.0	0.9	0.312	0		
As^{78}_{33} (b)	91 min	1.27×10^{-4}	2×10^{-2}	0.25	1.4	0.508	0.88	0.614	3.76
				0.25	2.8	1.18	0.24	1.31	3.31
				0.25	4.1	1.80	0.09	1.74	2.92
				0.25	3.5	1.52			
Se^{79}_{34}	6.5×10^4 yr	3.38×10^{-13}	4×10^{-2}	1.0	0.16	0.044	0		
Se^{81}	17 min	6.80×10^{-4}	0.133	1.0	1.38	0.527	0		
Se^{83} (b)	25 min	4.62×10^{-4}	0.21	0.80	0.91	0.321	0.32	1.3	3.31
				0.20	2.52	1.05	0.71	0.801	3.68
							0.58	0.512	3.77
							0.73	0.356	3.71
							0.34	0.226	3.46
							0.23	2.0	2.92
Br^{83}_{35}	2.4 hr	8.02×10^{-5}	0.48	1.0	0.94	0.337	1.0	0.051	5.95
Br^{84} (b)	30 min	3.85×10^{-4}	1.1	0.35	1.72	0.67	0.60	1.89	2.96
				0.16	2.53	1.05	0.42	0.89	3.63
				0.09	3.56	1.54			
				0.40	4.68	2.05			
Kr^{83m}_{36}	114 min	1.01×10^{-4}	0.48	0			1.0	0.0322	17.02
							1.0	0.0093	7.49
Kr^{85m}	4.36 hr	4.41×10^{-5}	1.5	0.80	0.835	0.294	0.2	0.305	3.65
							0.8	0.1495	3.07

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(\mathrm{sec}^{-1})$	Yield (%)	Beta Particles: Fraction f_1	Beta Particles: E_o(Mev)	Beta Particles: $\bar{E}$(Mev)	Gamma Transition: Fraction f_2	Gamma Transition: E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
Kr^{85}	10.27 yr	2.14×10^{-9}	0.3	1.0	0.695	0.236	0.007	0.514	3.77
Kr^{87}	78 min	1.48×10^{-4}	2.7	0.25	1.27	0.476	0.25	2.3	2.81
				0.75	3.63	1.58	0.25	1.89	2.96
							0.25	0.41	3.76
Kr^{88}	2.77 hr	6.95×10^{-5}	3.7	0.70	0.52	0.165	0.18	2.19	2.86
				0.10	0.9	0.318	0.15	1.85	3.63
				0.20	2.7	1.13	0.14	1.55	3.13
							0.04	1.20	3.37
							0.23	0.85	3.65
							0.05	0.365	3.72
							0.35	0.191	3.31
							0.07	0.163	3.17
							0.07	0.028	2.41
Rb^{87}_{37}	6.2×10^{10} yr	3.54×10^{-19}	2.7	1.0	0.275	0.079	0		
Rb^{88}	17.8 min	6.49×10^{-4}	3.7	0.09	2.5	1.03	0.024	2.8	2.67
				0.13	3.6	1.56	0.22	1.86	2.99
				0.78	5.3	2.32	0.14	0.9	3.62
Rb^{89}	15.4 min	7.5×10^{-4}	4.8	1.0	4.5	1.98	0		
Rb^{91}	14 min	8.25×10^{-4}	5.7	1.0	3.0	1.26			
Sr^{89}_{38}	54 days	1.48×10^{-7}	4.8	1.0	1.46	0.55	0		
Sr^{90}	28 yr	7.85×10^{-10}	5.9	1.0	0.61	0.20	0		

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles: Fraction f_1	Beta Particles: E_o(Mev)	Beta Particles: $\bar{E}$(Mev)	Gamma Transition: Fraction f_2	Gamma Transition: E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
Sr^{91}	9.7 hr	1.99×10^{-5}	5.9	0.07	0.62	0.203	0.07	1.413	3.23
				0.33	1.09	0.395	0.33	1.025	3.54
				0.29	1.36	0.481	0.07	0.747	3.70
				0.4	2.03	0.812	0.22	0.66	3.76
				0.27	2.67	1.11	0.33	0.64	3.76
Sr^{92}	2.7 hr	7.13×10^{-5}	6.1	1.0	1.14	0.44	0		
Y^{90}_{39}	64.5 hr	2.98×10^{-6}	5.9	1.0	2.18	0.87	0.004	1.4	3.23
Y^{91m}	51 min	2.26×10^{-4}	2.4	0			1.0	0.551	3.77
Y^{91}	58 days	1.38×10^{-7}	5.9	1.0	1.54	0.60	0.003	1.22	3.39
Y^{92}	3.6 hr	5.35×10^{-5}	6.1	0.11	1.3	0.50	0.021	2.4	2.78
				0.12	2.7	1.12	0.11	1.45	3.23
				0.77	3.6	1.54	0.23	0.94	3.63
Y^{93}	10 hr	1.93×10^{-5}	6.5	1.0	3.1	1.21	1.0	0.7	3.72
Y^{94}	16.5 min	7.00×10^{-4}	6.5	1.0	5.4	2.41	1.0	1.4	3.23
Y^{95}	10.5 min	1.10×10^{-3}	6.4	1.0	3.66	1.58	0		
Zr^{93}_{40}	1.1×10^6 yr	2.31×10^{-14}	6.5	1.0	0.063	0.016	0		
Zr^{95}	63 days	1.27×10^{-7}	6.4	0.57	0.364	0.109	0.98	0.717	3.72
				0.42	0.396	0.122			
				0.01	0.883	0.34			
Zr^{97}	17 hr	1.13×10^{-5}	6.2	1.0	1.91	0.76			

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles: Fraction f_1	E_o(Mev)	$\bar{E}$(Mev)	Gamma Transition: Fraction f_2	E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
Nb^{93m}_{41}	4.2 yr	5.24×10^{-9}	2.1	0			1.0	0.0292	22
Nb^{95m}	90 hr	2.14×10^{-6}	0.06	0			1.0	0.235	3.49
Nb^{95}	35 days	2.29×10^{-7}	6.4	1.0	0.16	0.044	1.0	0.745	3.71
Nb^{97m}	60 sec	1.16×10^{-2}	6.2	0			1.0	0.747	3.70
Nb^{97}	72.1 min	1.60×10^{-4}	6.2	1.0	1.267	0.468	1.0	0.665	3.76
Mo^{99}_{42}	67 hr	2.88×10^{-6}	6.1	0.13 0.87	0.45 1.23	0.139 0.448	0.13 0.13	0.78 0.14	3.68 3.00
Mo^{101}	14.6 min	7.91×10^{-4}	5.0	0.7 0.3	1.2 2.2	0.436 0.886	0.7 1.0	0.96 0.191	3.63 2.96
Mo^{102}	12 min	9.63×10^{-4}	4.2	1.0	0.92	0.312	0		
Tc^{99m}_{43}	6.04 hr	3.19×10^{-5}	~0.6	0			1.0	0.141	3.00
Tc^{99}	2.12×10^5 yr	1.04×10^{-13}	6.1	1.0	0.29	0.121	0		
Tc^{101}	14 min	8.25×10^{-4}	5.0	1.0	1.2	0.435	1.0	0.30	3.63
Tc^{102}	< 25 sec	2.77×10^{-2}	4.2	1.0	3.31	1.40	0		
Ru^{103}_{44}	41 days	1.96×10^{-7}	2.9	0.95 0.05	0.217 0.698	0.060 0.226	0.95	0.498	3.77
Ru^{105}	4.5 hr	4.28×10^{-5}	0.9	1.0	1.15	0.411	1.0	0.726	3.71

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles Fraction f_1	E_o(Mev)	$\bar{E}$(Mev)	Gamma Transition Fraction f_2	E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
Ru^{106}	1.0 yr	2.20×10^{-8}	0.38	1.0	0.0392	0.009	0		
Rh_{45}^{103m}	54 min	2.14×10^{-4}	2.9	0			1.0	0.040	10.12
Rh^{105m}	45 sec	1.54×10^{-2}	0.9	0			1.0	0.13	2.94
Rh^{106}	30 sec	2.31×10^{-2}	0.38	0.06	1.0	0.350	0.0025	2.41	2.78
				0.03	2.0	0.79	0.005	1.55	3.13
				0.12	2.44	0.98	0.02	1.045	3.54
				0.11	3.1	1.30	0.01	0.87	3.63
				0.68	3.53	1.52	0.12	0.624	3.76
							0.25	0.513	3.77
Rh^{107}	26 min	4.44×10^{-4}	0.2	1.0	1.2	0.434	0		
Rh^{109}	< 1 hr	1.93×10^{-4}	0.028	1.0	2.39	0.967	0		
Pd_{46}^{107}	7.5×10^{6} yr	2.92×10^{-15}	0.2	1.0	0.04	0.010	0		
Pd^{109}	13.6 hr	1.42×10^{-5}	0.028	1.0	0.961	0.327	0		
Pd^{111} (b)	22 min	5.25×10^{-4}	0.018	1.0	2.13	0.849	0		
Pd^{112}	21 hr	9.17×10^{6}	0.011	1.0	0.2	0.055	1.0	0.018	84.6
Ag_{47}^{109m}	39.2 sec	1.77×10^{-2}	0.028	0			1.0	0.088	3.07
Ag^{111}	7.6 days	1.06×10^{-6}	0.018	0.08	0.70	0.228	0.01	0.243	3.50
				0.01	0.80	0.268	0.08	0.340	3.71
				0.91	1.04	0.362			

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles: Fraction f_1	Beta Particles: E_o(Mev)	Beta Particles: $\overline{E}$(Mev)	Gamma Transition: Fraction f_2	Gamma Transition: E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
Ag^{112}(b)	3.2 hr	6.02×10^{-5}	0.011	0.15	1.0	0.348	0.11	1.4	3.23
				0.20	2.7	1.11	0.40	0.62	3.76
				0.40	3.5	1.49	0.12	2.1	2.89
				0.25	4.1	1.77			
Ag^{113}	5.3 hr	3.63×10^{-5}	0.01	1.0	2.0	0.69	0		
Cd^{113m}_{48}	5.1 yr	4.30×10^{-9}		1.0	0.59	0.187	0		
Cd^{117m}	2.9 hr	6.66×10^{-5}	0.01	0			1.0	0.79	3.68
Cd^{117}	50 min	2.31×10^{-4}	0.01	0.50	0.7	0.325	0.50	1.4	3.23
				0.38	1.8	0.388	0.38	0.425	3.75
				0.12	2.3	0.402			
Cd^{118}	~ 30 min	3.85×10^{-4}	0.01	1.0	1.09	0.385	0		
In^{115m}_{49}	4.5 hr	4.28×10^{-5}	0.0098	0.06	0.83	0.281	0.94	0.335	3.68
In^{115}	6×10^{14} yr	3.66×10^{-23}	0.0099	1.0	0.63	0.20	0		
In^{117m}	1.9 hr	1.01×10^{-4}	0.01	0.23	1.62	0.613	0.22	0.311	3.67
				0.55	1.77	0.677	0.78	0.161	3.16
In^{117}	1.1 hr	1.75×10^{-4}	2×10^{-3}	1.0	0.74	0.242	1.0	0.565	3.75
							1.0	0.161	3.16
In^{118}	4.5 min	2.57×10^{-3}	0.01	1.0	1.5	0.561	0		
In^{119}	17.5 min	6.60×10^{-4}	0.01	1.0	2.7	1.11	0		

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles: Fraction f_1	Beta Particles: E_o(Mev)	Beta Particles: $\bar{E}$(Mev)	Gamma Transition: Fraction f_2	Gamma Transition: E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
Sn^{121}_{50}	27.5 hr	7.00×10^{-6}	0.014	1.0	0.383	0.114	0		
Sn^{123}	39.5 min	2.92×10^{-4}	0.014	1.0	1.26	0.451	1.0	0.153	3.13
Sn^{125}	9.4 days	8.53×10^{-7}	0.012	0.05	0.40	0.119	0.05	1.90	2.96
				0.95	2.37	0.948			
Sn^{126}	50 min	2.31×10^{-4}	0.1	1.0	2.55	1.03	0		
Sn^{127}	1.5 hr	1.28×10^{-4}	0.24	1.0	4.84	2.09	0		
Sb^{125}_{51}	2.7 yr	8.14×10^{-9}	0.023	0.29	0.125	0.033			
				0.45	0.300	0.068	0.12	0.601	3.76
				0.12	0.414	0.123	0.17	0.465	3.76
				0.14	0.612	0.201	0.45	0.425	3.75
							0.17	0.175	3.23
							0.57	0.035	13.7
Sb^{126}	9 hr	2.14×10^{-5}	0.10	1.0	1.0	0.346	1.0	0.90	3.62
							1.0	0.40	3.75
Sb^{127}	93 hr	2.07×10^{-6}	0.25	1.0	1.2	0.429	1.0	0.72	3.71
Sb^{128}	1.1 hr	1.75×10^{-4}	0.5	1.0	5.68	2.44	0		
Sb^{129}	4.6 hr	4.32×10^{-5}	1.0	1.0	4.42	1.89	0		
Sb^{131}	21 min	5.50×10^{-4}	2.7	1.0	5.44	2.33	0		
Te^{125m}_{52}	58 days	1.38×10^{-7}	0.003	0			1.0	0.11	2.90

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles Fraction f_1	Beta Particles E_o(Mev)	Beta Particles $\bar{E}$(Mev)	Gamma Transition Fraction f_2	Gamma Transition E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
Te^{127m}	90 days	8.82×10^{-8}	0.056	0			1.0	0.0885	3.07
Te^{127}	9.3 hr	2.07×10^{-5}	0.25	1.0	0.7	0.227	0		
Te^{129^m}	33 days	2.43×10^{-7}	0.34	0			1.0	0.106	2.90
Te^{129}	72 min	1.60×10^{-4}	1.0	1.0	1.8	0.687	1.0 1.0	0.8 0.3	3.67 3.63
Te^{131m}	30 hr	6.42×10^{-5}	0.44	0			1.0	0.177	3.23
Te^{131}	24.8 min	4.66×10^{-4}	2.9	0.45 0.55	1.4 2.0	0.513 0.780	0.45 1.0	0.7 0.16	3.68 3.16
Te^{132}	77 hr	2.50×10^{-6}	4.4	1.0	0.22	0.061	1.0	0.231	3.49
Te^{133m}	63 min	1.83×10^{-4}	4.6	0			1.0	0.40	3.75
Te^{133}	2 min	5.78×10^{-3}	6.0	0.7 0.3	1.3 2.4	0.469 0.962	0.7 1.0	1.0 0.60	3.54 3.76
Te^{134}	44 min	2.63×10^{-4}	6.7	1.0	3.8	1.62	0		
I^{129}_{53}	1.72×10^{7} yr	1.28×10^{-15}	1.0	1.0	0.15	0.040	1.0	0.039	10.12
I^{131}	8.05 days	9.96×10^{-7}	2.9	0.028 0.093 0.872 0.007	0.250 0.335 0.608 0.815	0.070 0.097 0.196 0.270	0.03 0.09 0.80 0.053	0.722 0.637 0.364 0.284	3.71 3.76 3.72 3.59

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles: Fraction f_1	Beta Particles: E_o(Mev)	Beta Particles: $\bar{E}$(Mev)	Gamma Transition: Fraction f_2	Gamma Transition: E_m(Mev)	$\sigma \times 10^5$ (cm^{-1} soft tiss.)
I^{132}	2.4 hr	8.02×10^{-5}	4.4	0.15	0.7	0.230	0.02	2.2	2.85
				0.20	0.9	0.300	0.05	1.96	2.97
				0.23	1.16	0.406	0.11	1.40	3.25
				0.24	1.53	0.550	0.08	1.16	3.45
				0.18	2.12	0.828	0.20	0.96	3.63
							0.75	0.777	3.70
							1.0	0.673	3.75
							0.06	0.624	3.76
							0.25	0.528	3.76
I^{133}	20.8 hr	9.25×10^{-6}	6.5	0.06	0.5	0.154	0.01	1.4	3.25
				0.94	1.4	0.512	0.05	0.85	3.65
							0.94	0.53	3.76
I^{134}	52.5 min	2.20×10^{-4}	7.6	0.70	1.5	0.556	0.35	1.78	2.90
				0.30	2.5	1.01	0.35	1.10	3.47
							0.30	0.86	3.63
I^{135}	6.68 hr	2.89×10^{-5}	5.9	0.35	0.5	0.154	0.5	1.8	2.88
				0.40	1.0	0.346	0.5	1.27	3.35
				0.25	1.4	0.512			
Xe_{54}^{131m}	12.0 days	6.68×10^{-7}	0.03	0			1.0	0.163	3.17
Xe^{133m}	2.3 days	3.49×10^{-6}	0.16	0			1.0	0.233	3.49
Xe^{133}	5.27 days	1.52×10^{-6}	6.5	1.0	0.345	0.100	1.0	0.081	3.22
Xe^{133m}	15.6 min	7.4×10^{-4}	1.8	0			1.0	0.52	3.76
Xe^{135}	9.13 hr	2.11×10^{-5}	6.2	0.05	0.548	0.172	0.04	0.60	3.76
				0.95	0.910	0.316	0.01	0.37	3.74
							0.96	0.25	3.54

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles: Fraction f_1	Beta Particles: E_o(Mev)	Beta Particles: $\bar{E}$(Mev)	Gamma Transition: Fraction f_2	Gamma Transition: E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
Xe^{138}	17 min	6.79×10^{-4}	5.5	1.0	3.02	1.25	0		
Cs^{135}_{55}	3×10^6 yr	7.33×10^{-15}	6.2	1.0	0.21	0.058	0		
Cs^{137}	26.6 yr	8.27×10^{-10}	5.9	0.92	0.523	0.161	0		
				0.08	1.17	0.410			
Cs^{138}	32 min	3.62×10^{-4}	5.8	0.33	2.0	0.778	1.0	1.44	3.23
				0.10	2.9	1.19	0.43	0.98	3.57
				0.67	3.4	1.43	0.33	0.463	3.77
Ba^{137m}_{56}	2.6 min	4.44×10^{-3}	5.4	0			1.0	0.661	3.75
Ba^{139}	85 min	1.36×10^{-4}	6.0	0.19	0.82	0.276	0.19	1.43	3.25
				0.66	2.23	0.878	0.66	0.163	3.16
				0.15	2.38	0.944			
Ba^{140}	12.8 days	6.27×10^{-7}	6.3	0.40	0.480	0.147	0.30	0.54	3.77
				0.60	1.022	0.351	0.10	0.30	3.63
							0.10	0.16	3.13
							1.0	0.03	20.1
Ba^{141}	18 min	6.42×10^{-4}	5.9	1.0	2.8	1.14	0		
La^{140}_{57}	40.2 hr	4.79×10^{-6}	6.3	0.7	1.32	0.475	0.01	3.0	3.63
				0.2	1.67	0.624	0.054	2.5	2.76
				0.1	2.26	0.894	0.94	1.596	3.13
							0.29	0.815	3.68
							0.39	0.487	3.77
							0.054	0.329	3.70
							0.018	0.093	2.99

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles: Fraction f_1	E_o(Mev)	$\bar{E}$(Mev)	Gamma Transition: Fraction f_2	E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
La^{141}	3.7 hr	5.20×10^{-5}	6.0	0.05	0.9	0.305	0.05	1.5	3.13
				0.95	2.43	0.974			
La^{142}	74 min	1.56×10^{-4}	5.9	1.0	2.5	1.00	0.10	0.87	3.63
							0.90	0.63	3.76
La^{143}	19 min	6.08×10^{-4}	6.2	1.0	3.05	1.25	0.90	0.63	3.76
Ce^{141}_{58}	32 days	2.51×10^{-7}	6.0	0.67	0.442	0.132	0.67	0.145	3.08
				0.33	0.581	0.181			
Ce^{143}	32 hr	6.01×10^{-6}	6.2	0.30	0.71	0.230	0.152	0.660	3.75
				0.40	1.09	0.379	0.121	0.356	3.71
				0.30	1.39	0.501	0.606	0.289	3.62
							0.121	0.126	2.97
Ce^{144}	290 days	2.76×10^{-8}	6.1	0.30	0.170	0.060	0.1	0.134	2.96
				0.70	0.30	0.086	0.1	0.10	2.91
							0.1	0.0807	3.25
							0.1	0.054	5.37
							0.1	0.0337	15.7
Ce^{146}	13.9 min	8.31×10^{-4}	3.2	1.0	0.7	0.225	0.12	0.32	3.67
							0.24	0.27	3.57
							0.36	0.22	3.44
							0.07	0.142	3.00
							0.57	0.110	2.90
Pr^{143}_{59}	13.7 days	5.85×10^{-7}	6.2	1.0	0.932	0.314	0		
Pr^{144}	17.5 min	6.60×10^{-4}	6.1	0.03	0.8	0.28	0.01	2.185	2.65
				0.02	2.3	0.908	0.02	1.48	3.19
				0.95	2.98	1.21	0.04	0.695	3.76

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles: Fraction f_1	E_o(Mev)	$\bar{E}$(Mev)	Gamma Transition: Fraction f_2	E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
Pr^{145}	6.0 hr	3.21×10^{-5}	4.2	1.0	1.7	0.632	0		
Pr^{146}	24.4 min	4.73×10^{-4}	3.3	0.44	2.2	0.858	0.33	1.49	3.19
				0.56	3.7	1.55	0.22	0.75	3.70
							1.0	0.46	3.76
Nd_{60}^{147}	11.3 days	7.10×10^{-7}	2.6	0.25	0.38	0.111	0.25	0.532	3.76
				0.15	0.60	0.19	0.15	0.318	3.66
				0.60	0.83	0.28	0.60	0.092	2.96
Nd^{149}	2.0 hr	9.63×10^{-5}	1.3	1.0	1.5	0.54	0		
Nd^{151}(b)	15 min	7.7×10^{-4}	0.48	1.0	1.93	0.73	0.50	0.117	2.90
Pm_{61}^{147}	2.6 yr	8.46×10^{-9}	2.6	1.0	0.223	0.067	0		
Pm^{149}	54 hr	3.56×10^{-6}	1.3	1.0	1.05	0.357	1.0	0.285	3.61
Pm^{151}	27.5 hr	7.00×10^{-6}	0.5	1.0	1.1	0.378	0.081	0.715	3.74
							0.28	0.340	3.70
							0.15	0.25	3.53
							0.21	0.177	3.23
							0.44	0.069	3.74
Sm_{62}^{151}	93 yr	2.37×10^{-10}	0.5	1.0	0.076	0.019	1.0	0.019	7.48
Sm^{153}	47 hr	4.10×10^{-6}	0.15	0.10	0.26	0.073	0.10	0.538	3.76
				0.29	0.64	0.198	0.73	0.103	2.91
				0.44	0.70	0.223	0.29	0.0691	3.74
				0.17	0.81	0.264			

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles: Fraction f_1	E_o (Mev)	$\overline{E}$(Mev)	Gamma Transition: Fraction f_2	E_m(Mev)	$\sigma \times 10^5$ (cm^{-1} soft tiss.)
Sm^{155}	23.5 min	4.91×10^{-4}	0.031	1.0	1.8	0.675	1.0	0.246	3.52
							1.0	0.105	2.90
Sm^{156}	10 hr	1.93×10^{-5}	0.013	1.0	0.9	0.342			
Eu^{155}_{63}	1.7 yr	1.29×10^{-8}	0.031	0.84	0.152	0.041			
				0.16	0.252	0.071	1.0	0.105	2.90
							1.0	0.0858	3.13
Eu^{156}	15.4 days	5.21×10^{-7}	0.013	0.6	0.5	0.150	0.6	2.0	2.90
				0.4	2.4	0.945			
H^3_1	12.26 yr	1.80×10^{-9}		1.0	0.018	0.0055	0		
Be^7_4	53.6 days	1.50×10^{-7}		0			0.12	0.48	3.78
C^{14}_6	5568 yr	3.95×10^{-12}		1.0	0.156	0.05	0		
Na^{22}_{11}	2.58 yr	8.51×10^{-9}		1.0	0.544(+)	0.193	1.0	1.3	3.31
Na^{24}	15.05 hr	1.28×10^{-5}		1.0	1.392	0.56	1.0	1.368	3.30
							1.0	2.754	2.68
P^{32}_{15}	14.3 days	5.60×10^{-7}		1.0	1.710	0.70	0		
S^{35}_{16}	89 days	9.02×10^{-8}		1.0	0.167	0.0492			
Cl^{36}_{17}	3.08×10^5 yr	7.15×10^{-14}		1.0	0.714	0.295	0		

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles Fraction f_1	E_o(Mev)	$\bar{E}$(Mev)	Gamma Transition Fraction f_2	E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
K_{19}^{42}	12.46 hr	1.55×10^{-5}		0.8 0.2	3.54 1.98	1.52 0.821	0.2	1.51	3.17
Ca_{20}^{45}	165 days	4.86×10^{-8}		1.0	0.256	0.077	0		
Sc_{21}^{48}	44 hr	4.37×10^{-6}		1.0	0.65	0.221	1.0 1.0 1.0	1.33 1.05 0.99	3.30 3.50 3.55
Mn_{25}^{54}	290 days			0			1.0	0.84	3.64
Mn^{56}	2.58 hr			0.15 0.25 0.60	0.75 1.05 2.86	0.263 0.39 1.23	0.20 0.30 1.0	2.13 1.81 0.845	2.90 3.03 3.63
Fe_{26}^{55}	2.94 yr	7.47×10^{-9}		0			1.0	0.0059	3 510
Fe^{59}	44.3 days	1.81×10^{-7}		0.46 0.53 0.003	0.271 0.462 1.561	0.081 0.148 0.620	0.43 0.57 0.028	1.289 1.098 0.191	3.32 3.54 3.31
Co_{27}^{60}	5.24 yr	4.20×10^{-9}		1.0	0.314	0.093	1.0 1.0	1.32 1.17	3.28 3.41
Cu_{29}^{64}	12.9 hr	1.49×10^{-5}		0.39 0.19	0.57 0.65(+)	0.188 0.215	0.42	0.0075	1420
Zn_{30}^{65}	246.4 days	3.25×10^{-8}		0.017	0.325(+)	0.097	0.983 0.51	0.0082 1.12	1082 3.44

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(\text{sec}^{-1})$	Yield (%)	Beta Particles Fraction f_1	Beta Particles E_o(Mev)	Beta Particles $\bar{E}$(Mev)	Gamma Transition Fraction f_2	Gamma Transition E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
Cr^{51}	27.8 days	2.87×10^{-7}		0			0.0005	0.645	3.76
							0.092	0.320	3.67
Rh^{105}	36.5 hr	5.27×10^{-6}		0.10	0.25	0.0702	0.10	0.322	3.67
				0.57	0.90	0.312			
Cs^{134}_{55}	2.3 yr	9.52×10^{-9}		0.32	0.083	0.083	0.093	1.367	3.28
							0.058	1.168	3.42
				0.05	0.215	0.059	0.017	1.038	3.51
				0.50	0.655	0.21	0.15	0.801	3.68
							0.76	0.796	3.69
				0.13	0.683	0.22	0.85	0.605	3.75
							0.13	0.569	3.75
							0.075	0.563	3.75
Eu^{152}_{63}	9.3 yr	2.07×10^{-5}		0.82	1.88	0.71	0.047	0.233	3.48
							0.34	0.148	3.07
							1.09	0.135	2.97
							0.12	0.122	2.90
W^{181}_{74}	145 days	5.52×10^{-8}		0			0.067	0.139	2.99
							0.15	0.131	2.95
							0.14	0.126	2.92
W^{185}	75.8 days	1.06×10^{-7}		1.0	0.428	0.125	0		
W^{187}	24 hr	8.02×10^{-6}		0.7	0.63	0.196	1.0	0.69	3.74
				0.3	1.33	0.46			
Pb^{203}_{82}	52 hr	3.69×10^{-6}		0			1.0	0.144	3.03
							1.0	0.122	2.92

APPENDIX II, continued

Nuclide	Half-life	Decay Constant $\lambda(sec^{-1})$	Yield (%)	Beta Particles Fraction f_1	Beta Particles E_o(Mev)	Beta Particles $\bar{E}$(Mev)	Gamma Transition Fraction f_2	Gamma Transition E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
U^{239}	23.5 min	4.90×10^{-4}		1.0	1.21	0.399	0.83 0.17	0.074 0.022	3.46 48.4
Np^{239}	2.35 days	3.42×10^{-6}		0.105 0.48 0.135 0.28	0.68 0.437 0.393 0.332	0.208 0.128 0.111 0.093	0.80 0.03 0.105 0.15 0.021 0.69	0.106 0.21 0.23 0.278 0.335 0.022	2.90 3.42 3.48 3.61 3.68 48.4
Bi^{207}	8.0 yr	2.75×10^{-9}		0			1.0 1.0 1.0	1.06 0.57 0.088	3.48 3.77 3.10
Tl^{201}	72 hr	2.68×10^{-6}		0			2.0	0.083	3.17
Tl^{204}	3.8 yr	5.79×10^{-9}		1.0	0.765	0.238	0		
Pu^{239}	2.4×10^4 yr	9.16×10^{-13}		0			0.15	0.053	5.61
Pu^{240}	6.6×10^3 yr	3.34×10^{-12}		0			0.25	0.05	6.19
Pu^{241}	13.2 yr	1.67×10^{-9}		1.0	0.0205	0.0516	0.05	0.10	2.90
Pb^{210}	22 yr	1.00×10^{-9}		1.0	0.017	0.0429	1.0	0.047	7.10
Bi^{210}		1.61×10^{-6}		1.0	1.17	0.388	0		
Pb^{204m}	66.9 min	1.72×10^{-4}		0			0.94 0.99 0.91	0.375 0.899 0.912	3.75 3.63 3.63

APPENDIX II, continued

Nuclide	Half-life	Decay Constant	Yield	Beta Particles: Fraction f_1	E_o (Mev)	$\bar{E}$(Mev)	Gamma Transition: Fraction f_2	E_m(Mev)	$\sigma \times 10^5$ (cm^{-1}, soft tiss.)
Au^{196}	6.18 days	1.31×10^{-6}		0.06	0.259	0.0715	0.06	0.426	3.74
							0.90	0.356	3.74
							0.26	0.333	3.68
							0.99	0.068	3.87
Au^{198}	2.70 days	2.97×10^{-6}		0.01	0.287	0.0803	0.0018	1.087	3.48
				0.99	0.962	0.323	0.0082	0.675	3.74
							0.998	0.412	3.74
Pt^{195m}	4.1 days	1.96×10^{-6}		0			0.91	0.13	2.97
							0.090	0.0988	2.93
							0.30	0.0308	18.7
							1.0	0.0684	3.87
Hg^{203}	47 days	1.71×10^{-7}		1.0	0.212	0.0575	0.86	0.279	3.61
							0.14	0.746	3.46
Pu^{238}	86.4 yr	2.54×10^{-10}		0			0.0001	0.099	2.93
							0.0004	0.044	8.12
							0.28	0.017	105
U^{237}	6.75 days	1.19×10^{-6}		0.96	0.248	0.0677	0.38	0.06	4.59
							0.24	0.208	3.48
							0.016	0.332	3.68
							0.631	0.103	2.90
							0.37	0.022	48.4

(a) Parent radionuclides with $T_{1/2} < 10$ m and fission yield (%) $< 10^{-2}$ not included.

(b) Decay scheme from Nuclear Data Sheets simplified for external dose calculations: E_o = maximum beta-ray energy. $\bar{E}$ = average beta-ray energy. E_m = energy of gamma radiation. σ = linear energy absorption coefficient, cm^{-1}.

References

1. J. O. Blomeke and M. F. Todd, Uranium-235 Fission-Product Production as a Function of Thermal Neutron Flux, Irradiation Time and Decay Time. 1. Atomic Concentrations and Gross Totals, ORNL-2127 (August 19, 1957).

2. Radiological Health Handbook, U. S. Department of Health, Education, and Welfare, Public Health Service, Revised Edition, September 1960.

3. Nuclear Data Sheets, 1959-1965, Academic Press, New York.

APPENDIX III

LISTING OF RADIONUCLIDES FOR SUBMERSION DOSE RATES IN WATER CONTAINING INITIALLY 1 MICROCURIE PER GRAM

TIME 0.

NO.	BETA DOSE NUCLIDE	BETA DOSE REMS/HR	GAMMA DOSE NUCLIDE	GAMMA DOSE REMS/HR	TOTAL DOSE NUCLIDE	TOTAL DOSE REMS/HR
1	SB 128	0.26027E 01	NA 24	0.87936E 01	NA 24	0.93909E 01
2	Y 94	0.25707E 01	SC 48	0.71893E 01	SC 48	0.74240E 01
3	SB 131	0.24853E 01	CO 60	0.53120E 01	CS 138	0.57197E 01
4	RB 88	0.22454E 01	LA 140	0.45034E 01	Y 94	0.55573E 01
5	SN 127	0.22293E 01	SE 83	0.44339E 01	CO 60	0.54112E 01
6	RB 89	0.21120E 01	PB 204M	0.44212E 01	LA 140	0.50865E 01
7	SB 129	0.20160E 01	CS 138	0.42969E 01	SE 83	0.49318E 01
8	TE 134	0.17280E 01	I 132	0.42794E 01	MN 56	0.48031E 01
9	Y 95	0.16853E 01	MN 56	0.38699E 01	I 132	0.47796E 01
10	TC 102	0.14933E 01	BI 207	0.36651E 01	BR 84	0.46685E 01
11	K 42	0.14722E 01	CS 134	0.33452E 01	PB 204M	0.44212E 01
12	Y 92	0.14669E 01	I 135	0.32747E 01	KR 87	0.38443E 01
13	BR 84	0.14518E 01	BR 84	0.32166E 01	PR 146	0.37108E 01
14	RH 106	0.14282E 01	Y 94	0.29867E 01	BA 139	0.36998E 01
15	CS 138	0.14228E 01	BA 139	0.28747E 01	BI 207	0.36651E 01
16	AG 112	0.14002E 01	SB 126	0.27733E 01	I 135	0.36163E 01
17	KR 87	0.13909E 01	TE 133	0.27733E 01	RB 88	0.35306E 01
18	RB 91	0.13440E 01	NA 22	0.27733E 01	CS 134	0.34984E 01
19	AS 78	0.13355E 01	I 134	0.27008E 01	AS 78	0.34929E 01
20	LA 143	0.13333E 01	KR 88	0.26254E 01	I 134	0.34391E 01
21	PR 146	0.13286E 01	EU 156	0.25600E 01	TE 133	0.34314E 01
22	Y 93	0.12907E 01	FE 59	0.25290E 01	SB 126	0.31424E 01
23	PR 144	0.12545E 01	KR 87	0.24533E 01	TE 129	0.30795E 01
24	BA 141	0.12160E 01	PR 146	0.23823E 01	EU 156	0.30592E 01
25	IN 119	0.11840E 01	TE 129	0.23467E 01	KR 88	0.30236E 01
26	SN 126	0.10987E 01	AS 78	0.21575E 01	NA 22	0.29792E 01
27	LA 142	0.10667E 01	MO 101	0.18411E 01	AG 112	0.27954E 01
28	RH 109	0.10315E 01	CD 117	0.18379E 01	Y 93	0.27840E 01
29	LA 141	0.10033E 01	SR 91	0.18045E 01	FE 59	0.26544E 01
30	SN 125	0.96699E 00	MN 54	0.17920E 01	SB 128	0.26027E 01
31	MN 56	0.93328E 00	CD 117M	0.16853E 01	SB 131	0.24853E 01
32	Y 90	0.92800E 00	NB 97M	0.15936E 01	SR 91	0.24632E 01
33	PD 111	0.90560E 00	NB 95	0.15893E 01	LA 142	0.24619E 01
34	BA 139	0.82509E 00	RU 105	0.15488E 01	MO 101	0.24501E 01
35	ZR 97	0.81067E 00	IN 117	0.15488E 01	Y 92	0.23759E 01
36	ND 151	0.77867E 00	SB 127	0.15360E 01	SN 127	0.22293E 01
37	P 32	0.74667E 00	ZR 95	0.14990E 01	CD 117	0.22199E 01
38	I 134	0.73835E 00	Y 93	0.14933E 01	K 42	0.21165E 01
39	AG 113	0.73600E 00	W 187	0.14720E 01	RB 89	0.21120E 01
40	TE 129	0.73280E 00	NB 97	0.14187E 01	SB 129	0.20160E 01
41	SM 155	0.72000E 00	BA 137M	0.14101E 01	SB 127	0.19936E 01
42	TE 131	0.70384E 00	LA 142	0.13952E 01	RU 105	0.19872E 01
43	PR 145	0.67413E 00	AG 112	0.13952E 01	RH 106	0.19540E 01
44	SR 91	0.65872E 00	RB 88	0.12851E 01	NB 97	0.19179E 01
45	TE 133	0.65803E 00	ZN 65	0.12358E 01	IN 117	0.18069E 01
46	Y 91	0.64000E 00	I 133	0.11834E 01	MN 54	0.17920E 01
47	EU 152	0.62101E 00	Y 91M	0.11755E 01	W 187	0.17655E 01
48	MO 101	0.60907E 00	I 131	0.11108E 01	TE 134	0.17280E 01
49	IN 118	0.59840E 00	XE 135M	0.11093E 01	TE 131	0.17172E 01
50	NA 24	0.59733E 00	AU 196	0.10664E 01	I 133	0.17066E 01

APPENDIX III, continued

51	SR 89	0.58667E 00	TE 131	0.10133E 01	Y 95	0.16853E 01
52	LA 140	0.58315E 00	RU 103	0.10093E 01	CD 117M	0.16853E 01
53	ND 149	0.57600E 00	Y 92	0.90901E 00	NB 95	0.16363E 01
54	SE 81	0.56213E 00	AU 198	0.89316E 00	ZR 95	0.16236E 01
55	IN 117M	0.54756E 00	TE 133M	0.85333E 00	NB 97M	0.15936E 01
56	I 133	0.52322E 00	SB 125	0.83652E 00	TC 102	0.14933E 01
57	I 132	0.50018E 00	SM 155	0.74880E 00	SM 155	0.14688E 01
58	NB 97	0.49920E 00	CE 143	0.71205E 00	PR 144	0.14235E 01
59	EU 156	0.49920E 00	IN 115M	0.67179E 00	BA 137M	0.14101E 01
60	SE 83	0.49792E 00	K 42	0.64427E 00	RB 91	0.13440E 01
61	SN 123	0.48107E 00	TC 101	0.64000E 00	LA 143	0.13333E 01
62	SR 92	0.46933E 00	PM 149	0.60800E 00	I 131	0.13069E 01
63	TC 101	0.46400E 00	XE 135	0.57109E 00	ZN 65	0.12375E 01
64	RH 107	0.46293E 00	PB 203	0.56747E 00	AU 198	0.12351E 01
65	SB 127	0.45760E 00	PM 151	0.55071E 00	BA 141	0.12160E 01
66	RU 105	0.43840E 00	CE 146	0.54408E 00	IN 119	0.11840E 01
67	MO 99	0.43502E 00	HG 203	0.53415E 00	Y 91M	0.11755E 01
68	U 239	0.42560E 00	RH 106	0.52588E 00	SN 125	0.11697E 01
69	BI 210	0.41387E 00	BA 140	0.50773E 00	LA 141	0.11633E 01
70	CD 118	0.41067E 00	ND 147	0.50325E 00	XE 135M	0.11093E 01
71	PM 151	0.40320E 00	NB 95M	0.50133E 00	CE 143	0.11077E 01
72	KR 88	0.39819E 00	XE 133M	0.49707E 00	TC 101	0.11040E 01
73	CE 143	0.39563E 00	TE 132	0.49280E 00	SN 126	0.10987E 01
74	CD 117	0.38206E 00	EU 152	0.47586E 00	EU 152	0.10969E 01
75	PM 149	0.38080E 00	PT 195M	0.43697E 00	RU 103	0.10821E 01
76	AG 111	0.37370E 00	IN 117M	0.41387E 00	AU 196	0.10709E 01
77	SB 126	0.36907E 00	EU 155	0.40704E 00	RH 109	0.10315E 01
78	SM 156	0.36480E 00	KR 85M	0.38528E 00	PM 149	0.98880E 00
79	BR 83	0.35947E 00	NP 239	0.38222E 00	IN 117M	0.96143E 00
80	PD 109	0.34880E 00	TE 131M	0.37760E 00	PM 151	0.95391E 00
81	AU 198	0.34194E 00	XE 131M	0.34773E 00	Y 90	0.93995E 00
82	I 135	0.34165E 00	SN 123	0.32640E 00	SB 125	0.92513E 00
83	PR 143	0.33493E 00	U 237	0.32249E 00	PD 111	0.90560E 00
84	GE 78	0.33280E 00	SM 153	0.31793E 00	ND 151	0.90347E 00
85	MO 102	0.33280E 00	TC 99M	0.30080E 00	XE 135	0.90048E 00
86	XE 135	0.32939E 00	RH 105M	0.27733E 00	TE 133M	0.85333E 00
87	RH 105	0.31824E 00	MO 99	0.25515E 00	ZR 97	0.81067E 00
88	C 136	0.31467E 00	TE 125M	0.23467E 00	SN 123	0.80747E 00
89	W 187	0.29355E 00	TE 129M	0.22613E 00	BA 140	0.79509E 00
90	BA 140	0.28736E 00	CE 141	0.20725E 00	CE 146	0.78408E 00
91	IN 117	0.25813E 00	SN 125	0.20267E 00	P 32	0.74667E 00
92	TL 204	0.25387E 00	TE 127M	0.18880E 00	ND 147	0.74245E 00
93	KR 85	0.25173E 00	AG 109M	0.18773E 00	AG 113	0.73600E 00
94	KR 85M	0.25088E 00	XE 133	0.17280E 00	MO 99	0.69016E 00
95	TE 127	0.24213E 00	PR 144	0.16907E 00	IN 115M	0.68977E 00
96	CE 146	0.24000E 00	LA 141	0.16000E 00	PR 145	0.67413E 00
97	ND 147	0.23920E 00	U 239	0.13901E 00	Y 91	0.64781E 00
98	SC 48	0.23467E 00	ND 151	0.12480E 00	KR 85M	0.63616E 00
99	SM 153	0.22157E 00	BE 7	0.12288E 00	IN 118	0.59840E 00
100	SR 90	0.21333E 00	BR 83	0.10880E 00	HG 203	0.59549E 00
101	IN 115	0.21333E 00	PB 210	0.10027E 00	SR 89	0.58667E 00

APPENDIX III, continued

102	NA 22	0.20587E 00	W 181	0.99420E-01	ND 149	0.57600E 00
103	CD 113M	0.19947E 00	KR 83M	0.88533E-01	PB 203	0.56747E 00
104	I 131	0.19604E 00	CE 144	0.86699E-01	U 239	0.56461E 00
105	CS 137	0.19298E 00	RH 103M	0.85333E-01	SE 81	0.56213E 00
106	CE 141	0.15805E 00	I 129	0.83200E-01	TE 132	0.55787E 00
107	CS 134	0.15316E 00	RH 105	0.68693E-01	SM 153	0.53950E 00
108	XE 138	0.13333E 00	KR 85	0.65792E-01	NP 239	0.51481E 00
109	W 185	0.13333E 00	CR 51	0.63493E-01	NB 95M	0.50133E 00
110	NP 239	0.13259E 00	AG 111	0.63211E-01	XE 133M	0.49707E 00
111	TC 99	0.12907E 00	NB 93M	0.62293E-01	SR 92	0.46933E 00
112	FE 59	0.12540E 00	SM 151	0.40533E-01	BR 83	0.46827E 00
113	ZR 95	0.12455E 00	PD 112	0.38400E-01	RH 107	0.46293E 00
114	CU 64	0.12178E 00	TL 201	0.35413E-01	EU 155	0.45589E 00
115	SN 121	0.12160E 00	PU 240	0.26667E-01	PT 195M	0.43697E 00
116	XE 133	0.10667E 00	PU 239	0.16960E-01	AG 111	0.43691E 00
117	CO 60	0.99200E-01	FE 55	0.12587E-01	BI 210	0.41387E 00
118	SB 125	0.88608E-01	Y 90	0.11947E-01	CD 118	0.41067E 00
119	RB 87	0.84267E-01	PU 241	0.10667E-01	U 237	0.39181E 00
120	CE 144	0.83413E-01	PU 238	0.10213E-01	RH 105	0.38693E 00
121	CA 45	0.82133E-01	Y 91	0.78080E-02	TE 131M	0.37760E 00
122	RU 103	0.72853E-01	CU 64	0.67200E-02	CE 141	0.36530E 00
123	PM 147	0.71467E-01	GE 78	0.0	SM 156	0.36480E 00
124	U 237	0.69325E-01	SE 79	0.0	PD 109	0.34880E 00
125	TE 132	0.65067E-01	SE 81	0.0	XE 131M	0.34773E 00
126	CS 135	0.61867E-01	RB 87	0.0	PR 143	0.33493E 00
127	HG 203	0.61333E-01	RB 89	0.0	GE 78	0.33280E 00
128	PD 112	0.58667E-01	RB 91	0.0	MO 102	0.33280E 00
129	PU 241	0.55040E-01	SR 89	0.0	KR 85	0.31753E 00
130	C 14	0.53333E-01	SR 90	0.0	C 136	0.31467E 00
131	S 35	0.52480E-01	SR 92	0.0	TC 99M	0.30080E 00
132	EU 155	0.48853E-01	Y 95	0.0	XE 133	0.27947E 00
133	SE 79	0.46933E-01	ZR 93	0.0	RH 105M	0.27733E 00
134	NB 95	0.46933E-01	ZR 97	0.0	TL 204	0.25387E 00
135	PB 210	0.45760E-01	MO 102	0.0	TE 127	0.24213E 00
136	I 129	0.42667E-01	TC 99	0.0	TE 125M	0.23467E 00
137	SM 151	0.20267E-01	TC 102	0.0	TE 129M	0.22613E 00
138	IN 115M	0.17984E-01	RU 106	0.0	SR 90	0.21333E 00
139	ZR 93	0.17067E-01	RH 107	0.0	IN 115	0.21333E 00
140	PD 107	0.10667E-01	RH 109	0.0	CD 113M	0.19947E 00
141	RU 106	C.96000E-02	PD 107	0.0	CS 137	0.19298E 00
142	H 3	0.58667E-02	PD 109	0.0	TE 127M	0.18880E 00
143	AU 196	0.45760E-02	PD 111	0.0	AG 109M	0.18773E 00
144	ZN 65	0.17589E-02	AG 113	0.0	CE 144	0.17011E 00
145	KR 83M	0.0	CD 113M	0.0	PB 210	0.14603E 00
146	Y 91M	0.0	CD 118	0.0	XE 138	0.13333E 00
147	NB 93M	0.0	IN 115	0.0	W 185	0.13333E 00
148	NB 95M	0.0	IN 118	0.0	TC 99	0.12907E 00
149	NB 97M	0.0	IN 119	0.0	CU 64	0.12850E 00
150	TC 99M	0.0	SN 121	0.0	I 129	0.12587E 00
151	RH 103M	0.0	SN 126	0.0	BE 7	0.12288E 00
152	RH 105M	0.0	SN 127	0.0	SN 121	0.12160E 00

APPENDIX III, continued

153	AG 109M	0.0	SB 128	0.0	W 181	0.99420E-01
154	CD 117M	0.0	SB 129	0.0	PD 112	0.97067E-01
155	TE 125M	0.0	SB 131	0.0	KR 83M	0.88533E-01
156	TE 127M	0.0	TE 127	0.0	RH 103M	0.85333E-01
157	TE 129M	0.0	TE 134	0.0	RB 87	0.84267E-01
158	TE 131M	0.0	XE 138	0.0	CA 45	0.82133E-01
159	TE 133M	0.0	CS 135	0.0	PM 147	0.71467E-01
160	XE 131M	0.0	CS 137	0.0	PU 241	0.65707E-01
161	XE 133M	0.0	BA 141	0.0	CR 51	0.63493E-01
162	XE 135M	0.0	LA 143	0.0	NB 93M	0.62293E-01
163	BA 137M	0.0	PR 143	0.0	CS 135	0.61867E-01
164	BE 7	0.0	PR 145	0.0	SM 151	0.60800E-01
165	FE 55	0.0	ND 149	0.0	C 14	0.53333E-01
166	MN 54	0.0	PM 147	0.0	S 35	0.52480E-01
167	W 181	0.0	SM 156	0.0	SE 79	0.46933E-01
168	PB 203	0.0	H 3	0.0	TL 201	0.35413E-01
169	PT 195M	0.0	C 14	0.0	PU 240	0.26667E-01
170	PU 238	0.0	P 32	0.0	ZR 93	0.17067E-01
171	BI 207	0.0	S 35	0.0	PU 239	0.16960E-01
172	TL 201	0.0	C 136	0.0	FE 55	0.12587E-01
173	PU 239	0.0	CA 45	0.0	PD 107	0.10667E-01
174	PU 240	0.0	W 185	0.0	PU 238	0.10213E-01
175	PB 204M	0.0	TL 204	0.0	RU 106	0.96000E-02
176	CR 51	0.0	BI 210	0.0	H 3	0.58667E-02

APPENDIX IV

LISTING OF RADIONUCLIDES FOR SUBMERSION DOSE RATES IN AIR CONTAINING
INITIALLY 1 MICROCURIE PER GRAM

TIME 0.

	BETA DOSE		GAMMA DOSE		TOTAL DOSE	
NO.	NUCLIDE	REMS/HR	NUCLIDE	REMS/HR	NUCLIDE	REMS/HR
1	SB 128	0.29687E 01	NA 24	0.50151E 01	NA 24	0.56964E 01
2	Y 94	0.29322E 01	SC 48	0.41002E 01	Y 94	0.46355E 01
3	SB 131	0.28348E 01	CO 60	0.30295E 01	SC 48	0.43678E 01
4	RB 88	0.25612E 01	LA 140	0.25683E 01	CS 138	0.40734E 01
5	SN 127	0.25428E 01	SE 83	0.25287E 01	BR 84	0.34905E 01
6	RB 89	0.24090E 01	PB 204M	0.25215E 01	RB 88	0.32941E 01
7	SB 129	0.22995E 01	CS 138	0.24506E 01	MN 56	0.32716E 01
8	TE 134	0.19710E 01	I 132	0.24406E 01	LA 140	0.32335E 01
9	Y 95	0.19223E 01	MN 56	0.22070E 01	CO 60	0.31426E 01
10	TC 102	0.17033E 01	BI 207	0.20902E 01	SE 83	0.30966E 01
11	K 42	0.16792E 01	CS 134	0.19078E 01	I 132	0.30111E 01
12	Y 92	0.16732E 01	I 135	0.18676E 01	KR 87	0.29857E 01
13	BR 84	0.16560E 01	BR 84	0.18345E 01	SB 128	0.29687E 01
14	RH 106	0.16290E 01	Y 94	0.17033E 01	PR 146	0.28740E 01
15	CS 138	0.16228E 01	BA 139	0.16395E 01	SB 131	0.28348E 01
16	AG 112	0.15971E 01	SB 126	0.15817E 01	AS 78	0.27537E 01
17	KR 87	0.15865E 01	TE 133	0.15817E 01	BA 139	0.25806E 01
18	RB 91	0.15330E 01	NA 22	0.15817E 01	SN 127	0.25428E 01
19	AS 78	0.15233E 01	I 134	0.15403E 01	PB 204M	0.25215E 01
20	LA 143	0.15208E 01	KR 88	0.14973E 01	RB 89	0.24090E 01
21	PR 146	0.15154E 01	EU 156	0.14600E 01	AG 112	0.23928E 01
22	Y 93	0.14722E 01	FE 59	0.14423E 01	I 134	0.23825E 01
23	PR 144	0.14309E 01	KR 87	0.13992E 01	TE 133	0.23322E 01
24	BA 141	0.13870E 01	PR 146	0.13587E 01	Y 93	0.23238E 01
25	IN 119	0.13505E 01	TE 129	0.13383E 01	SB 129	0.22995E 01
26	SN 126	0.12532E 01	AS 78	0.12304E 01	I 135	0.22573E 01
27	LA 142	0.12167E 01	MO 101	0.10500E 01	Y 92	0.21916E 01
28	RH 109	0.11765E 01	CD 117	0.10482E 01	TE 129	0.21742E 01
29	LA 141	0.11443E 01	SR 91	0.10291E 01	BI 207	0.20902E 01
30	SN 125	0.11030E 01	MN 54	0.10220E 01	CS 134	0.20825E 01
31	MN 56	0.10645E 01	CD 117M	0.96117E 00	K 42	0.20467E 01
32	Y 90	0.10585E 01	NB 97M	0.90885E 00	EU 156	0.20294E 01
33	PD 111	0.10329E 01	NB 95	0.90642E 00	LA 142	0.20124E 01
34	BA 139	0.94111E 00	RU 105	0.88330E 00	SB 126	0.20026E 01
35	ZR 97	0.92467E 00	IN 117	0.88330E 00	TE 134	0.19710E 01
36	ND 151	0.88817E 00	SB 127	0.87600E 00	KR 88	0.19515E 01
37	P 32	0.85167E 00	ZR 95	0.85490E 00	RH 106	0.19289E 01
38	I 134	0.84218E 00	Y 93	0.85167E 00	Y 95	0.19223E 01
39	AG 113	0.83950E 00	W 187	0.83950E 00	NA 22	0.18165E 01
40	TE 129	0.83585E 00	NB 97	0.80908E 00	SR 91	0.17805E 01
41	SM 155	0.82125E 00	BA 137M	0.80422E 00	MO 101	0.17447E 01
42	TE 131	0.80282E 00	AG 112	0.79570E 00	TC 102	0.17033E 01
43	PR 145	0.76893E 00	LA 142	0.79570E 00	FE 59	0.15854E 01
44	SR 91	0.75135E 00	RB 88	0.73292E 00	RB 91	0.15330E 01
45	TE 133	0.75056E 00	ZN 65	0.70477E 00	PR 144	0.15273E 01
46	Y 91	0.73000E 00	I 133	0.67488E 00	LA 143	0.15208E 01
47	EU 152	0.70834E 00	Y 91M	0.67038E 00	CD 117	0.14839E 01
48	MO 101	0.69472E 00	I 131	0.63353E 00	SB 127	0.13979E 01
49	IN 118	0.68255E 00	XE 135M	0.63267E 00	BA 141	0.13870E 01
50	NA 24	0.68133E 00	AU 196	0.60816E 00	RU 105	0.13833E 01

APPENDIX IV, continued

51	SR 89	0.66917E 00	TE 131	0.57792E 00	TE 131	0.13807E 01
52	LA 140	0.66515E 00	RU 103	0.57560E 00	NB 97	0.13785E 01
53	ND 149	0.65700E 00	Y 92	0.51842E 00	IN 119	0.13505E 01
54	SE 81	0.64118E 00	AU 198	0.50938E 00	I 133	0.12717E 01
55	IN 117M	0.62456E 00	TE 133M	0.48667E 00	SN 126	0.12532E 01
56	I 133	0.59680E 00	SB 125	0.47708E 00	SM 155	0.12483E 01
57	I 132	0.57052E 00	SM 155	0.42705E 00	LA 141	0.12356E 01
58	NB 97	0.56940E 00	CE 143	0.40609E 00	SN 125	0.12186E 01
59	EU 156	0.56940E 00	IN 115M	0.38313E 00	IN 117	0.11777E 01
60	SE 83	0.56794E 00	K 42	0.36743E 00	RH 109	0.11765E 01
61	SN 123	0.54872E 00	TC 101	0.36500E 00	W 187	0.11743E 01
62	SR 92	0.53533E 00	PM 149	0.34675E 00	Y 90	0.10653E 01
63	TC 101	0.52925E 00	XE 135	0.32570E 00	PD 111	0.10329E 01
64	RH 107	0.52803E 00	PB 203	0.32363E 00	MN 54	0.10220E 01
65	SB 127	0.52195E 00	PM 151	0.31408E 00	ZR 95	0.99697E 00
66	RU 105	0.50005E 00	CE 146	0.31030E 00	EU 152	0.97973E 00
67	MO 99	0.49619E 00	HG 203	0.30463E 00	CD 117M	0.96117E 00
68	U 239	0.48545E 00	RH 106	0.29991E 00	NB 95	0.95995E 00
69	BI 210	0.47207E 00	BA 140	0.28957E 00	ND 151	0.95934E 00
70	CD 118	0.46842E 00	ND 147	0.28701E 00	ZR 97	0.92467E 00
71	PM 151	0.45990E 00	NB 95M	0.28592E 00	NB 97M	0.90885E 00
72	KR 88	0.45418E 00	XE 133M	0.28348E 00	AU 198	0.89941E 00
73	CE 143	0.45126E 00	TE 132	0.28105E 00	TC 101	0.89425E 00
74	CD 117	0.43579E 00	EU 152	0.27139E 00	IN 117M	0.86060E 00
75	PM 149	0.43435E 00	PT 195M	0.24921E 00	CE 143	0.85736E 00
76	AG 111	0.42625E 00	IN 117M	0.23603E 00	I 131	0.85713E 00
77	SB 126	0.42097E 00	EU 155	0.23214E 00	P 32	0.85167E 00
78	SM 156	0.41610E 00	KR 85M	0.21973E 00	AG 113	0.83950E 00
79	BR 83	0.41002E 00	NP 239	0.21798E 00	BA 137M	0.80422E 00
80	PD 109	0.39785E 00	TE 131M	0.21535E 00	PM 149	0.78110E 00
81	AU 198	0.39003E 00	XE 131M	0.19832E 00	PM 151	0.77398E 00
82	I 135	0.38970E 00	SN 123	0.18615E 00	PR 145	0.76893E 00
83	PR 143	0.38203E 00	U 237	0.18392E 00	SN 123	0.73487E 00
84	GE 78	0.37960E 00	SM 153	0.18132E 00	Y 91	0.73445E 00
85	MO 102	0.37960E 00	TC 99M	0.17155E 00	ZN 65	0.70677E 00
86	XE 135	0.37571E 00	RH 105M	0.15817E 00	XE 135	0.70141E 00
87	RH 105	0.36299E 00	MO 99	0.14551E 00	IN 118	0.68255E 00
88	C 136	0.35892E 00	TE 125M	0.13383E 00	Y 91M	0.67038E 00
89	W 187	0.33483E 00	TE 129M	0.12897E 00	SR 89	0.66917E 00
90	BA 140	0.32777E 00	CE 141	0.11820E 00	RU 103	0.65870E 00
91	IN 117	0.29443E 00	SN 125	0.11558E 00	ND 149	0.65700E 00
92	TL 204	0.28957E 00	TE 127M	0.10767E 00	MO 99	0.64171E 00
93	KR 85	0.28713E 00	AG 109M	0.10707E 00	SE 81	0.64118E 00
94	KR 85M	0.28616E 00	XE 133	0.98550E-01	XE 135M	0.63267E 00
95	TE 127	0.27618E 00	PR 144	0.96421E-01	BA 140	0.61734E 00
96	CE 146	0.27375E 00	LA 141	0.91250E-01	AU 196	0.61338E 00
97	ND 147	0.27284E 00	U 239	0.79278E-01	CE 146	0.58405E 00
98	SC 48	0.26767E 00	ND 151	0.71175E-01	SB 125	0.57815E 00
99	SM 153	0.25273E 00	BE 7	0.70080E-01	U 239	0.56473E 00
100	SR 90	0.24333E 00	BR 83	0.62050E-01	ND 147	0.55985E 00
101	IN 115	0.24333E 00	PB 210	0.57183E-01	SR 92	0.53533E 00

APPENDIX IV, continued

102	NA 22	0.23482E 00	W 181	0.56700E-01	RH 107	0.52803E 00
103	CD 113M	0.22752E 00	KR 83M	0.50492E-01	KR 85M	0.50589E 00
104	I 131	0.22360E 00	CE 144	0.49445E-01	TE 133M	0.48667E 00
105	CS 137	0.22012E 00	RH 103M	0.48667E-01	BR 83	0.47207E 00
106	CE 141	0.18027E 00	I 129	0.47450E-01	BI 210	0.47207E 00
107	CS 134	0.17470E 00	RH 105	0.39177E-01	CD 118	0.46842E 00
108	XE 138	0.15208E 00	KR 85	0.37522E-01	AG 111	0.46230E 00
109	W 185	0.15208E 00	CR 51	0.36211E-01	SM 153	0.43404E 00
110	NP 239	0.15124E 00	AG 111	0.36050E-01	SM 156	0.41610E 00
111	TC 99	0.14722E 00	NB 93M	0.35527E-01	IN 115M	0.40364E 00
112	FE 59	0.14303E 00	SM 151	0.23117E-01	RH 105	0.40217E 00
113	ZR 95	0.14207E 00	PD 112	0.21900E-01	PD 109	0.39785E 00
114	CU 64	0.13891E 00	TL 201	0.20197E-01	PR 143	0.38203E 00
115	SN 121	0.13870E 00	PU 240	0.15208E-01	GE 78	0.37960E 00
116	XE 133	0.12167E 00	PU 239	0.96725E-02	MO 102	0.37960E 00
117	CO 60	0.11315E 00	FE 55	0.71783E-02	HG 203	0.37459E 00
118	SB 125	0.10107E 00	Y 90	0.68133E-02	NP 239	0.36922E 00
119	RB 87	0.96117E-01	PU 241	0.60833E-02	C 136	0.35892E 00
120	CE 144	0.95143E-01	PU 238	0.58248E-02	TE 132	0.35527E 00
121	CA 45	0.93683E-01	Y 91	0.44530E-02	KR 85	0.32466E 00
122	RU 103	0.83098E-01	CU 64	0.38325E-02	PB 203	0.32363E 00
123	PM 147	0.81517E-01	GE 78	0.0	CE 141	0.29847E 00
124	U 237	0.79073E-01	SE 79	0.0	TL 204	0.28957E 00
125	TE 132	0.74217E-01	SE 81	0.0	EU 155	0.28786E 00
126	CS 135	0.70567E-01	RB 87	0.0	NB 95M	0.28592E 00
127	HG 203	0.69958E-01	RB 89	0.0	XE 133M	0.28348E 00
128	PD 112	0.66917E-01	RB 91	0.0	TE 127	0.27618E 00
129	PU 241	0.62780E-01	SR 89	0.0	U 237	0.26299E 00
130	C 14	0.60833E-01	SR 90	0.0	PT 195M	0.24921E 00
131	S 35	0.59860E-01	SR 92	0.0	SR 90	0.24333E 00
132	EU 155	0.55723E-01	Y 95	0.0	IN 115	0.24333E 00
133	SE 79	0.53533E-01	ZR 93	0.0	CD 113M	0.22752E 00
134	NB 95	0.53533E-01	ZR 97	0.0	XE 133	0.22022E 00
135	PB 210	0.52195E-01	MO 102	0.0	CS 137	0.22012E 00
136	I 129	0.48667E-01	TC 99	0.0	TE 131M	0.21535E 00
137	SM 151	0.23117E-01	TC 102	0.0	XE 131M	0.19832E 00
138	IN 115M	0.20513E-01	RU 106	0.0	TC 99M	0.17155E 00
139	ZR 93	0.19467E-01	RH 107	0.0	RH 105M	0.15817E 00
140	PD 107	0.12167E-01	RH 109	0.0	XE 138	0.15208E 00
141	RU 106	0.10950E-01	PD 107	0.0	W 185	0.15208E 00
142	H 3	0.66917E-02	PD 109	0.0	TC 99	0.14722E 00
143	AU 196	0.52195E-02	PD 111	0.0	CE 144	0.14459E 00
144	ZN 65	0.20063E-02	AG 113	0.0	CU 64	0.14274E 00
145	KR 83M	0.0	CD 113M	0.0	SN 121	0.13870E 00
146	Y 91M	0.0	CD 118	0.0	TE 125M	0.13383E 00
147	NB 93M	0.0	IN 115	0.0	TE 129M	0.12897E 00
148	NB 95M	0.0	IN 118	0.0	PB 210	0.10938E 00
149	NB 97M	0.0	IN 119	0.0	TE 127M	0.10767E 00
150	TC 99M	0.0	SN 121	0.0	AG 109M	0.10707E 00
151	RH 103M	0.0	SN 126	0.0	RB 87	0.96117E-01
152	RH 105M	0.0	SN 127	0.0	I 129	0.96117E-01

APPENDIX IV, continued

153	AG 109M	0.0	SB 128	0.0	CA 45	0.93683E-01
154	CD 117M	0.0	SB 129	0.0	PD 112	0.88817E-01
155	TE 125M	0.0	SB 131	0.0	PM 147	0.81517E-01
156	TE 127M	0.0	TE 127	0.0	CS 135	0.70567E-01
157	TE 129M	0.0	TE 134	0.0	BE 7	0.70080E-01
158	TE 131M	0.0	XE 138	0.0	PU 241	0.68863E-01
159	TE 133M	0.0	CS 135	0.0	C 14	0.60833E-01
160	XE 131M	0.0	CS 137	0.0	S 35	0.59860E-01
161	XE 133M	0.0	BA 141	0.0	W 181	0.56700E-01
162	XE 135M	0.0	LA 143	0.0	SE 79	0.53533E-01
163	BA 137M	0.0	PR 143	0.0	KR 83M	0.50492E-01
164	BE 7	0.0	PR 145	0.0	RH 103M	0.48667E-01
165	FE 55	0.0	ND 149	0.0	SM 151	0.46233E-01
166	MN 54	0.0	PM 147	0.0	CR 51	0.36211E-01
167	W 181	0.0	SM 156	0.0	NB 93M	0.35527E-01
168	PB 203	0.0	H 3	0.0	TL 201	0.20197E-01
169	PT 195M	0.0	C 14	0.0	ZR 93	0.19467E-01
170	PU 238	0.0	P 32	0.0	PU 240	0.15208E-01
171	BI 207	0.0	S 35	0.0	PD 107	0.12167E-01
172	TL 201	0.0	C 136	0.0	RU 106	0.10950E-01
173	PU 239	0.0	CA 45	0.0	PU 239	0.96725E-02
174	PU 240	0.0	W 185	0.0	FE 55	0.71783E-02
175	PB 204M	0.0	TL 204	0.0	H 3	0.66917E-02
176	CR 51	0.0	BI 210	0.0	PU 238	0.58248E-02

APPENDIX V

LISTING OF RADIONUCLIDES FOR DOSE RATES ABOVE GROUND SURFACE CONTAMINTED
INITIALLY WITH 1 MICROCURIE PER SQ CM

DISTANCE= 0.760000E 02

TIME C.TAU 0

	BETA DOSE		GAMMA DOSE		TOTAL DOSE	
NO.	NUCLIDE	REMS/HR	NUCLIDE	REMS/HR	NUCLIDE	REMS/HR
1	Y 94	0.43197E 01	NA 24	0.61992E 00	Y 94	0.45504E 01
2	SB 128	0.41843E 01	SC 48	0.58642E 00	RB 88	0.41891E 01
3	SB 131	0.41496E 01	CO 60	0.42319E 00	SB 128	0.41843E 01
4	RB 89	0.41391E 01	PB 204M	0.37860E 00	SB 131	0.41496E 01
5	SN 127	0.41133E 01	I 132	0.36462E 00	RB 89	0.41391E 01
6	RB 88	0.40930E 01	SE 83	0.36289E 00	SN 127	0.41133E 01
7	SB 129	0.40091E 01	LA 140	0.34953E 00	CS 138	0.40631E 01
8	Y 95	0.38823E 01	CS 138	0.34170E 00	SB 129	0.40091E 01
9	TE 134	0.38699E 01	BI 207	0.30762E 00	Y 95	0.38823E 01
10	CS 138	0.37214E 01	MN 56	0.30153E 00	TE 134	0.38699E 01
11	TC 102	0.36993E 01	CS 134	0.28748E 00	TC 102	0.36993E 01
12	K 42	0.36358E 01	I 135	0.24343E 00	K 42	0.36848E 01
13	RB 91	0.35586E 01	BR 84	0.24293E 00	BR 84	0.36235E 01
14	Y 92	0.35259E 01	TE 133	0.23814E 00	Y 92	0.35988E 01
15	RH 106	0.35135E 01	SB 126	0.23805E 00	RH 106	0.35591E 01
16	LA 143	0.34923E 01	Y 94	0.23064E 00	RB 91	0.35586E 01
17	BR 84	0.33806E 01	BA 139	0.21996E 00	LA 143	0.34923E 01
18	BA 141	0.33635E 01	NA 22	0.21907E 00	Y 93	0.34748E 01
19	IN 119	0.33476E 01	I 134	0.20884E 00	KR 87	0.34723E 01
20	Y 93	0.33442E 01	FE 59	0.20633E 00	PR 146	0.34516E 01
21	PR 144	0.33344E 01	KR 88	0.20533E 00	AS 78	0.34345E 01
22	AG 112	0.33094E 01	TE 129	0.20150E 00	AG 112	0.34197E 01
23	KR 87	0.32952E 01	PR 146	0.19752E 00	BA 141	0.33635E 01
24	AS 78	0.32555E 01	EU 156	0.18143E 00	IN 119	0.33476E 01
25	PR 146	0.32541E 01	AS 78	0.17896E 00	PR 144	0.33475E 01
26	SN 126	0.32097E 01	KR 87	0.17717E 00	LA 142	0.32729E 01
27	LA 142	0.31501E 01	MN 54	0.15364E 00	SN 126	0.32097E 01
28	RH 109	0.31188E 01	SR 91	0.15335E 00	RH 109	0.31188E 01
29	LA 141	0.29913E 01	MO 101	0.15159E 00	LA 141	0.30034E 01
30	SN 125	0.29172E 01	CD 117	0.14558E 00	SN 125	0.29318E 01
31	Y 90	0.29111E 01	CD 117M	0.14526E 00	Y 90	0.29120E 01
32	PD 111	0.28866E 01	NB 95	0.13863E 00	PD 111	0.28866E 01
33	ZR 97	0.26845E 01	NB 97M	0.13863E 00	MN 56	0.27633E 01
34	ND 151	0.25706E 01	RU 105	0.13509E 00	BA 139	0.27019E 01
35	P 32	0.25319E 01	SB 127	0.13398E 00	ZR 97	0.26845E 01
36	BA 139	0.24820E 01	IN 117	0.13177E 00	TE 129	0.26644E 01
37	TE 129	0.24629E 01	ZR 95	0.13110E 00	I 134	0.25740E 01
38	MN 56	0.24618E 01	Y 93	0.13061E 00	ND 151	0.25706E 01
39	SM 155	0.24199E 01	W 187	0.12895E 00	P 32	0.25319E 01
40	AG 113	0.24021E 01	NB 97	0.12541E 00	SM 155	0.24796E 01
41	I 134	0.23651E 01	ZN 65	0.12398E 00	NA 24	0.24094E 01
42	PR 145	0.22876E 01	BA 137M	0.12386E 00	AG 113	0.24021E 01
43	TE 131	0.22325E 01	LA 142	0.12274E 00	TE 131	0.23164E 01
44	Y 91	0.21815E 01	AG 112	0.11032E 00	PR 145	0.22876E 01
45	EU 152	0.20655E 01	I 133	0.10370E 00	TE 133	0.21875E 01
46	IN 118	0.20333E 01	Y 91M	0.10360E 00	Y 91	0.21821E 01
47	ND 149	0.19572E 01	XE 135M	0.97696E-01	LA 140	0.21392E 01
48	TE 133	0.19494E 01	I 131	0.96491E-01	EU 152	0.21003E 01
49	IN 117M	0.18517E 01	RB 88	0.96146E-01	IN 118	0.20333E 01
50	SR 91	0.18359E 01	AU 196	0.93540E-01	SR 91	0.19893E 01

APPENDIX V, continued

51	MO 101	0.17977E 01	RU 103	0.88953E-01	ND 149	0.19572E 01
52	LA 140	0.17897E 01	TE 131	0.83853E-01	MO 101	0.19493E 01
53	NA 24	0.17895E 01	AU 198	0.78365E-01	IN 117M	0.18847E 01
54	SR 89	0.17822E 01	TE 133M	0.74951E-01	I 132	0.17890E 01
55	SE 81	0.16790E 01	Y 92	0.72949E-01	SR 89	0.17822E 01
56	I 133	0.15431E 01	SB 125	0.67263E-01	SE 81	0.16790E 01
57	NB 97	0.14360E 01	CE 143	0.60908E-01	I 133	0.16468E 01
58	I 132	0.14244E 01	SM 155	0.59714E-01	SE 83	0.15757E 01
59	SN 123	0.13797E 01	BA 140	0.58955E-01	NB 97	0.15615E 01
60	TC 101	0.12917E 01	IN 115M	0.57904E-01	EU 156	0.14204E 01
61	RH 107	0.12887E 01	TC 101	0.54517E-01	SB 127	0.14078E 01
62	SB 127	0.12738E 01	PM 149	0.51700E-01	SN 123	0.14044E 01
63	SR 92	0.12568E 01	KR 83M	0.51381E-01	TC 101	0.13462E 01
64	EU 156	0.12389E 01	K 42	0.49009E-01	RU 105	0.13175E 01
65	SE 83	0.12128E 01	XE 135	0.48054E-01	RH 107	0.12887E 01
66	U 239	0.11913E 01	NP 239	0.46139E-01	SR 92	0.12568E 01
67	RU 105	0.11824E 01	PM 151	0.45851E-01	U 239	0.12068E 01
68	MO 99	0.11778E 01	RH 106	0.45679E-01	MO 99	0.11964E 01
69	BI 210	0.11314E 01	HG 203	0.45195E-01	BI 210	0.11314E 01
70	CD 118	0.10556E 01	CE 146	0.43552E-01	SB 126	0.10979E 01
71	PM 151	0.10457E C1	ND 147	0.42340E-01	PM 151	0.10915E 01
72	CE 143	0.97897E 00	NB 95M	0.41445E-01	CD 118	0.10556E 01
73	PM 149	0.94112E 00	PB 203	0.41197E-01	CE 143	0.10399E 01
74	AG 111	0.88455E 00	XE 133M	0.41092E-01	I 135	0.10106E 01
75	SB 126	0.85986E 00	TE 132	0.40739E-01	CD 117	0.99798E 00
76	CD 117	0.85240E 00	PT 195M	0.38744E-01	PM 149	0.99282E 00
77	KR 88	0.78529E 00	U 237	0.34863E-01	KR 88	0.99061E 00
78	PD 109	0.76916E 00	EU 152	0.34771E-01	AG 111	0.89004E 00
79	I 135	0.76716E 00	IN 117M	0.32923E-01	AU 198	0.83166E 00
80	BR 83	0.76667E 00	PD 112	0.31728E-01	SC 48	0.78333E 00
81	AU 198	0.75330E 00	KR 85M	0.30116E-01	BR 83	0.78049E 00
82	SM 156	0.72408E 00	TE 131M	0.29160E-01	PD 109	0.76916E 00
83	PR 143	0.70479E 00	XE 131M	0.26452E-01	SM 156	0.72408E 00
84	MO 102	0.68573E 00	SM 153	0.25305E-01	PR 143	0.70479E 00
85	GE 78	0.66057E 00	SN 123	0.24651E-01	XE 135	0.69949E 00
86	XE 135	0.65143E 00	TC 99M	0.22013E-01	MO 102	0.68573E 00
87	RH 105	0.59451E 00	NB 93M	0.21319E-01	W 187	0.67130E 00
88	BA 140	0.54776E 00	RH 105M	0.19998E-01	GE 78	0.66057E 00
89	W 187	0.54236E 00	MO 99	0.18645E-01	BA 140	0.60672E 00
90	KR 85M	0.43087E 00	TE 125M	0.16631E-01	RH 105	0.60043E 00
91	C 136	0.36210E 00	RH 103M	0.16410E-01	IN 117	0.46152E 00
92	TL 204	0.35477E 00	TE 129M	0.16026E-01	KR 85M	0.46099E 00
93	IN 117	0.32975E 00	I 129	0.15963E-01	CO 60	0.42339E 00
94	ND 147	0.32297E 00	U 239	0.15506E-01	CS 134	0.41462E 00
95	KR 85	0.26626E 00	CE 141	0.15487E-01	PB 204M	0.37860E 00
96	TE 127	0.26203E 00	SN 125	0.14661E-01	ND 147	0.36531E 00
97	CE 146	0.25973E 00	PB 210	0.14629E-01	C 136	0.36210E 00
98	SM 153	0.23865E 00	TE 127M	0.14037E-01	TL 204	0.35477E 00
99	SR 90	0.22421E 00	AG 109M	0.13958E-01	BI 207	0.30762E 00
100	PM 147	0.22337E 00	BR 83	0.13818E-01	CE 146	0.30328E 00
101	SC 48	0.19691E 00	XE 133	0.13401E-01	NA 22	0.29711E 00

APPENDIX V, continued

102	IN 115	0.15882E 00	PR 144	0.13146E-01	KR 85	0.27206E 00
103	CS 137	0.14387E 00	LA 141	0.12084E-01	SM 153	0.26395E 00
104	CS 134	0.12714E 00	BE 7	0.10879E-01	TE 127	0.26203E 00
105	I 131	0.12065E 00	PU 238	0.95730E-02	SR 90	0.22421E 00
106	CD 113M	0.11253E 00	CE 144	0.84126E-02	PM 147	0.22337E 00
107	NA 22	0.78046E-01	CU 64	0.81389E-02	FE 59	0.22315E 00
108	CU 64	0.74117E-01	W 181	0.71487E-02	I 131	0.21714E 00
109	CE 141	0.41614E-01	SM 151	0.61634E-02	IN 115	0.15882E 00
110	IN 115M	0.30493E-01	RH 105	0.59160E-02	MN 54	0.15364E 00
111	NP 239	0.28697E-01	KR 85	0.57986E-02	CD 117M	0.14526E 00
112	SB 125	0.20675E-01	AG 111	0.54911E-02	CS 137	0.14387E 00
113	FE 59	0.16819E-01	CR 51	0.54695E-02	ZR 95	0.14077E 00
114	RU 103	0.12926E-01	PU 240	0.34942E-02	NB 95	0.13863E 00
115	ZR 95	0.96713E-02	TL 201	0.26939E-02	NB 97M	0.13863E 00
116	W 185	0.88413E-02	FE 55	0.23429E-02	ZN 65	0.12399E 00
117	SN 121	0.28829E-02	PU 239	0.20309E-02	BA 137M	0.12386E 00
118	XE 133	0.77752E-03	Y 90	0.92257E-03	CD 113M	0.11253E 00
119	CO 60	0.20208E-03	PU 241	0.75597E-03	Y 91M	0.10360E 00
120	XE 138	0.14971E-03	Y 91	0.63049E-03	RU 103	0.10188E 00
121	TC 99	0.74378E-04	GE 78	0.0	XE 135M	0.97696E-01
122	CE 144	0.64853E-04	SE 79	0.0	AU 196	0.93541E-01
123	RB 87	0.18726E-04	SE 81	0.0	IN 115M	0.88397E-01
124	ZN 65	0.58603E-05	RB 87	0.0	SB 125	0.87938E-01
125	CA 45	0.43114E-05	RB 89	0.0	CU 64	0.82256E-01
126	U 237	0.17990E-05	RB 91	0.0	TE 133M	0.74951E-01
127	EU 155	0.45084E-06	SR 89	0.0	NP 239	0.74836E-01
128	AU 196	0.30787E-06	SR 90	0.0	CE 141	0.57101E-01
129	TE 132	0.77993E-07	SR 92	0.0	KR 83M	0.51381E-01
130	HG 203	0.24404E-07	Y 95	0.0	HG 203	0.45195E-01
131	CS 135	0.18324E-07	ZR 93	0.0	NB 95M	0.41445E-01
132	PD 112	0.34773E-08	ZR 97	0.0	PB 203	0.41197E-01
133	S 35	0.12418E-11	MO 102	0.0	XE 133M	0.41092E-01
134	SE 79	0.11928E-12	TC 99	0.0	TE 132	0.40739E-01
135	NB 95	0.11928E-12	TC 102	0.0	PT 195M	0.38744E-01
136	C 14	0.32852E-13	RU 106	0.0	U 237	0.34865E-01
137	I 129	0.24991E-14	RH 107	0.0	PD 112	0.31728E-01
138	SM 151	0.12246E-63	RH 109	0.0	TE 131M	0.29160E-01
139	KR 83M	0.0	PD 107	0.0	XE 131M	0.26452E-01
140	Y 91M	0.0	PD 109	0.0	TC 99M	0.22013E-01
141	ZR 93	0.0	PD 111	0.0	NB 93M	0.21319E-01
142	NB 93M	0.0	AG 113	0.0	RH 105M	0.19998E-01
143	NB 95M	0.0	CD 113M	0.0	TE 125M	0.16631E-01
144	NB 97M	0.0	CD 118	0.0	RH 103M	0.16410E-01
145	TC 99M	0.0	IN 115	0.0	TE 129M	0.16026E-01
146	RU 106	0.0	IN 118	0.0	I 129	0.15963E-01
147	RH 103M	0.0	IN 119	0.0	PB 210	0.14629E-01
148	RH 105M	0.0	SN 121	0.0	XE 133	0.14179E-01
149	PD 107	0.0	SN 126	0.0	TE 127M	0.14037E-01
150	AG 109M	0.0	SN 127	0.0	AG 109M	0.13958E-01
151	CD 117M	0.0	SB 128	0.0	BE 7	0.10879E-01
152	TE 125M	0.0	SB 129	0.0	PU 238	0.95730E-02

APPENDIX V, continued

153	TE 127M	0.0	SB 131	0.0	W 185	0.88413E-02
154	TE 129M	0.0	TE 127	0.0	CE 144	0.84774E-02
155	TE 131M	0.0	TE 134	0.0	W 181	0.71487E-02
156	TE 133M	0.0	XE 138	0.0	SM 151	0.61634E-02
157	XE 131M	0.0	CS 135	0.0	CR 51	0.54695E-02
158	XE 133M	0.0	CS 137	0.0	PU 240	0.34942E-02
159	XE 135M	0.0	BA 141	0.0	SN 121	0.28829E-02
160	BA 137M	0.0	LA 143	0.0	TL 201	0.26939E-02
161	H 3	0.0	PR 143	0.0	FE 55	0.23429E-02
162	BE 7	0.0	PR 145	0.0	PU 239	0.20309E-02
163	FE 55	0.0	ND 149	0.0	PU 241	0.75597E-03
164	MN 54	0.0	ND 151	0.0	XE 138	0.14971E-03
165	W 181	0.0	PM 147	0.0	TC 99	0.74378E-04
166	PB 203	0.0	SM 156	0.0	RB 87	0.18726E-04
167	PT 195M	0.0	EU 155	0.0	CA 45	0.43114E-05
168	PU 238	0.0	H 3	0.0	EU 155	0.45084E-06
169	BI 207	0.0	C 14	0.0	CS 135	0.18324E-07
170	TL 201	0.0	P 32	0.0	S 35	0.12418E-11
171	PU 239	0.0	S 35	0.0	SE 79	0.11928E-12
172	PU 240	0.0	C 136	0.0	C 14	0.32852E-13
173	PU 241	0.0	CA 45	0.0	ZR 93	0.0
174	PB 210	0.0	W 185	0.0	RU 106	0.0
175	PB 204M	0.0	TL 204	0.0	PD 107	0.0
176	CR 51	0.0	BI 210	0.0	H 3	0.0

APPENDIX VI

LISTING OF RADIONUCLIDES FOR ACCUMULATED SUBMERSION DOSE IN WATER CONTAINING INITIALLY 1 MICROCURIE PER GRAM

TIME 2600.

NO.	NUCLIDE	BETA DOSE REMS	NUCLIDE	GAMMA DOSE REMS	NUCLIDE	TOTAL DOSE REMS
1	C 136	0.13742E 06	BI 207	0.36531E 06	BI 207	0.36531E 06
2	TC 99	0.56362E 05	CO 60	0.35085E 06	CO 60	0.35740E 06
3	SR 90	0.53521E 05	CS 134	0.97608E 05	C 136	0.13742E 06
4	CS 137	0.47162E 05	NA 22	0.90525E 05	CS 134	0.10208E 06
5	KR 85	0.31546E 05	I 129	0.36591E 05	NA 22	0.97245E 05
6	CS 135	0.26970E 05	SB 125	0.28546E 05	TC 99	0.56362E 05
7	C 14	0.23224E 05	PB 210	0.22072E 05	I 129	0.55355E 05
8	SE 79	0.20496E 05	MN 54	0.18035E 05	SR 90	0.53521E 05
9	I 129	0.18764E 05	SM 151	0.14780E 05	CS 137	0.47162E 05
10	CD 113M	0.12871E 05	PU 240	0.11617E 05	KR 85	0.39791E 05
11	TL 204	0.12178E 05	ZN 65	0.10562E 05	PB 210	0.32145E 05
12	PB 210	0.10073E 05	EU 155	0.87649E 04	SB 125	0.31570E 05
13	PU 241	0.84925E 04	KR 85	0.82448E 04	CS 135	0.26970E 05
14	ZR 93	0.74496E 04	PU 239	0.74027E 04	C 14	0.23224E 05
15	SM 151	0.73901E 04	FE 59	0.38812E 04	SM 151	0.22170E 05
16	NA 22	0.67197E 04	PU 238	0.36779E 04	SE 79	0.20496E 05
17	CO 60	0.65520E 04	NB 93M	0.33014E 04	MN 54	0.18035E 05
18	PD 107	0.46571E 04	ZR 95	0.32787E 04	CD 113M	0.12871E 05
19	CS 134	0.44690E 04	NB 95	0.19279E 04	TL 204	0.12178E 05
20	SB 125	0.30237E 04	PU 241	0.16458E 04	PU 240	0.11617E 05
21	PM 147	0.23465E 04	RU 103	0.14304E 04	ZN 65	0.10577E 05
22	Y 91	0.12882E 04	EU 156	0.13649E 04	PU 241	0.10138E 05
23	SR 89	0.11011E 04	CE 144	0.87257E 03	EU 155	0.98168E 04
24	EU 155	0.10520E 04	HG 203	0.86769E 03	ZR 93	0.74496E 04
25	H 3	0.85195E 03	TE 127M	0.59461E 03	PU 239	0.74027E 04
26	CE 144	0.83951E 03	W 181	0.50030E 03	PD 107	0.46571E 04
27	CA 45	0.46944E 03	TE 125M	0.47236E 03	FE 59	0.40737E 04
28	P 32	0.37037E 03	FE 55	0.46804E 03	PU 238	0.36779E 04
29	W 185	0.34941E 03	SC 48	0.45699E 03	ZR 95	0.35511E 04
30	SN 125	0.31490E 03	I 131	0.30981E 03	NB 93M	0.33014E 04
31	ZR 95	0.27243E 03	LA 140	0.26116E 03	PM 147	0.23465E 04
32	EU 156	0.26615E 03	TE 129M	0.25850E 03	NB 95	0.19848E 04
33	FE 59	0.19244E 03	CE 141	0.22936E 03	CE 144	0.17121E 04
34	CE 141	0.17491E 03	BE 7	0.22756E 03	EU 156	0.16311E 04
35	S 35	0.16162E 03	AU 196	0.22612E 03	RU 103	0.15336E 04
36	PR 143	0.15904E 03	BA 140	0.22494E 03	Y 91	0.13040E 04
37	BA 140	0.12731E 03	SB 127	0.20612E 03	SR 89	0.11011E 04
38	RU 106	0.12121E 03	ND 147	0.19689E 03	HG 203	0.96733E 03
39	RU 103	0.10325E 03	NA 24	0.19083E 03	H 3	0.85195E 03
40	HG 203	0.99632E 02	XE 131M	0.14460E 03	TE 127M	0.59461E 03
41	AG 111	0.97929E 02	AU 198	0.83535E 02	W 181	0.50030E 03
42	ND 147	0.93584E 02	U 237	0.75277E 02	TE 125M	0.47236E 03
43	Y 90	0.86503E 02	SN 125	0.65998E 02	SC 48	0.47190E 03
44	BI 210	0.71406E 02	NB 95M	0.65074E 02	CA 45	0.46944E 03
45	SB 127	0.61406E 02	PT 195M	0.61930E 02	FE 55	0.46804E 03
46	NB 95	0.56930E 02	CR 51	0.61453E 02	CE 141	0.40427E 03
47	I 131	0.54673E 02	TE 132	0.54756E 02	SN 125	0.38089E 03
48	MO 99	0.41958E 02	W 187	0.50984E 02	P 32	0.37037E 03
49	LA 140	0.33817E 02	PM 149	0.47441E 02	I 131	0.36448E 03
50	AU 198	0.31981E 02	PB 203	0.42718E 02	BA 140	0.35225E 03

APPENDIX VI, continued

51	PM 149	0.29713E 02	XE 133M	0.39563E 02	W 185	0.34941E 03
52	K 42	0.26384E 02	SB 126	0.35999E 02	LA 140	0.29497E 03
53	ZR 97	0.19928E 02	I 133	0.35536E 02	ND 147	0.29047E 03
54	XE 133	0.19493E 02	CE 143	0.32911E 02	SB 127	0.26753E 03
55	Y 93	0.18576E 02	XE 133	0.31579E 02	TE 129M	0.25850E 03
56	CE 143	0.18286E 02	I 135	0.31475E 02	BE 7	0.22756E 03
57	RH 105	0.16774E 02	NP 239	0.31044E 02	AU 196	0.22709E 03
58	U 237	0.16182E 02	SR 91	0.25188E 02	NA 24	0.20380E 03
59	PM 151	0.16000E 02	MO 99	0.24609E 02	S 35	0.16162E 03
60	I 133	0.15712E 02	PM 151	0.21854E 02	PR 143	0.15904E 03
61	ZN 65	0.15034E 02	SM 153	0.21540E 02	XE 131M	0.14460E 03
62	SM 153	0.15011E 02	Y 93	0.21493E 02	RU 106	0.12121E 03
63	SC 48	0.14917E 02	AG 111	0.16565E 02	AU 198	0.11552E 03
64	SB 129	0.12963E 02	Y 91	0.15717E 02	AG 111	0.11449E 03
65	NA 24	0.12963E 02	I 132	0.14822E 02	U 237	0.91459E 02
66	NP 239	0.10769E 02	K 42	0.11546E 02	Y 90	0.87616E 02
67	W 187	0.10167E 02	KR 88	0.11067E 02	PM 149	0.77154E 02
68	SR 91	0.91949E 01	RU 105	0.10052E 02	BI 210	0.71406E 02
69	EU 152	0.83335E 01	XE 135	0.75183E 01	MO 99	0.66567E 02
70	Y 92	0.76162E 01	PB 204M	0.71402E 01	NB 95M	0.65074E 02
71	TE 132	0.72296E 01	CD 117M	0.70292E 01	TE 132	0.61985E 02
72	PD 109	0.68232E 01	AG 112	0.64378E 01	PT 195M	0.61930E 02
73	AG 112	0.64609E 01	EU 152	0.63857E 01	CR 51	0.61453E 02
74	PR 145	0.58336E 01	BA 139	0.58715E 01	W 187	0.61151E 02
75	AG 113	0.56321E 01	Y 92	0.47197E 01	I 133	0.51249E 02
76	LA 141	0.53593E 01	AS 78	0.47189E 01	CE 143	0.51196E 02
77	SM 156	0.52504E 01	KR 87	0.46046E 01	XE 133	0.51072E 02
78	SN 127	0.48380E 01	IN 115M	0.43600E 01	PB 203	0.42718E 02
79	SN 121	0.48254E 01	TE 129	0.40741E 01	NP 239	0.41814E 02
80	SB 126	0.47906E 01	TL 201	0.36705E 01	SB 126	0.40789E 02
81	XE 135	0.43363E 01	RH 105	0.36208E 01	Y 93	0.40069E 02
82	SB 128	0.41312E 01	I 134	0.34101E 01	XE 133M	0.39563E 02
83	I 135	0.32839E 01	CS 138	0.32972E 01	K 42	0.37930E 02
84	TE 127	0.32492E 01	SE 83	0.26659E 01	PM 151	0.37854E 02
85	AS 78	0.29210E 01	TC 99M	0.26193E 01	SM 153	0.36551E 02
86	RU 105	0.28453E 01	LA 142	0.24843E 01	I 135	0.34759E 02
87	KR 87	0.26106E 01	NB 97	0.24630E 01	SR 91	0.34383E 02
88	CU 64	0.22703E 01	IN 117	0.24584E 01	RH 105	0.20395E 02
89	LA 142	0.18993E 01	KR 85M	0.24268E 01	ZR 97	0.19928E 02
90	SR 92	0.18285E 01	BR 84	0.23208E 01	I 132	0.16555E 02
91	TE 134	0.18251E 01	CD 117	0.22100E 01	EU 152	0.14719E 02
92	PD 112	0.17771E 01	TE 131M	0.16338E 01	SB 129	0.12963E 02
93	I 132	0.17324E 01	Y 91M	0.14448E 01	AG 112	0.12899E 02
94	BA 139	0.16852E 01	MN 56	0.14390E 01	RU 105	0.12897E 02
95	KR 88	0.16784E 01	PR 146	0.13990E 01	KR 88	0.12745E 02
96	ND 149	0.16615E 01	TE 133M	0.12953E 01	Y 92	0.12336E 02
97	KR 85M	0.15802E 01	Y 94	0.11852E 01	XE 135	0.11855E 02
98	IN 117M	0.15059E 01	PD 112	0.11632E 01	AS 78	0.76399E 01
99	RH 109	0.14845E 01	IN 117M	0.11382E 01	BA 139	0.75567E 01
100	SN 126	0.13211E 01	Y 90	0.11136E 01	KR 87	0.72152E 01
101	TE 129	0.12722E 01	LA 141	0.85470E 00	PB 204M	0.71402E 01

APPENDIX VI, continued

102	SB 131	0.12552E 01	MO 101	0.64653E 00	CD 117M	0.70292E 01
103	BR 83	0.12450E 01	TE 131	0.60404E 00	PD 109	0.68232E 01
104	CS 138	0.10917E 01	RB 88	0.55004E 00	LA 141	0.62140E 01
105	BR 84	0.10475E 01	SM 155	0.42363E 00	PR 145	0.58336E 01
106	Y 94	0.10201E 01	XE 135M	0.41642E 00	AG 113	0.56321E 01
107	AU 196	0.97031E 00	BR 83	0.37684E 00	TE 129	0.53463E 01
108	RB 88	0.96107E 00	SN 123	0.31050E 00	SM 156	0.52504E 01
109	I 134	0.93225E 00	KR 83M	0.24349E 00	SN 127	0.48380E 01
110	NB 97	0.86667E 00	TC 101	0.21549E 00	SN 121	0.48254E 01
111	RB 89	0.78222E 00	CE 146	0.18187E 00	IN 115M	0.44767E 01
112	PR 146	0.78022E 00	TE 133	0.13328E 00	CS 138	0.43890E 01
113	GE 78	0.68988E 00	CU 64	0.12528E 00	LA 142	0.43837E 01
114	LA 143	0.60916E 00	RH 103M	0.11076E 00	I 134	0.43424E 01
115	PR 144	0.52797E 00	BA 137M	0.88221E-01	SB 128	0.41312E 01
116	BA 141	0.52613E 00	U 239	0.78803E-01	KR 85M	0.40071E 01
117	IN 119	0.49832E 00	PR 144	0.71156E-01	TL 201	0.36705E 01
118	PD 111	0.47915E 00	ND 151	0.45022E-01	BR 84	0.33683E 01
119	CD 117	0.45943E 00	NB 97M	0.38161E-01	NB 97	0.33296E 01
120	SN 123	0.45764E 00	RH 106	0.63237E-02	TE 127	0.32492E 01
121	RB 91	0.45252E 00	RH 105M	0.50024E-02	SE 83	0.29653E 01
122	Y 95	0.42559E 00	AG 109M	0.29462E-02	PD 112	0.29403E 01
123	TE 131	0.41955E 00	GE 78	-0.0	IN 117	0.28681E 01
124	IN 117	0.40974E 00	SE 79	-0.0	CD 117	0.26695E 01
125	SM 155	0.40733E 00	SE 81	-0.0	IN 117M	0.26442E 01
126	MN 56	0.34705E 00	RB 87	-0.0	TC 99M	0.26193E 01
127	SE 83	0.29937E 00	RB 89	-0.0	CU 64	0.23956E 01
128	CD 118	0.29630E 00	RB 91	-0.0	Y 94	0.22053E 01
129	RH 107	0.29159E 00	SR 89	-0.0	PR 146	0.21793E 01
130	ND 151	0.28090E 00	SR 90	-0.0	SR 92	0.18285E 01
131	U 239	0.24127E 00	SR 92	-0.0	TE 134	0.18251E 01
132	SE 81	0.22963E 00	Y 95	-0.0	MN 56	0.17861E 01
133	MO 101	0.21389E 00	ZR 93	-0.0	ND 149	0.16615E 01
134	TC 101	0.15623E 00	ZR 97	-0.0	TE 131M	0.16338E 01
135	IN 115M	0.11672E 00	MO 102	-0.0	BR 83	0.16219E 01
136	MO 102	0.95996E-01	TC 99	-0.0	RB 88	0.15111E 01
137	CE 146	0.80225E-01	TC 102	-0.0	RH 109	0.14845E 01
138	IN 118	0.64678E-01	RU 106	-0.0	Y 91M	0.14448E 01
139	XE 138	0.54546E-01	RH 107	-0.0	SN 126	0.13211E 01
140	TE 133	0.31624E-01	RH 109	-0.0	TE 133M	0.12953E 01
141	RH 106	0.17174E-01	PD 107	-0.0	SB 131	0.12552E 01
142	TC 102	0.14975E-01	PD 109	-0.0	TE 131	0.10236E 01
143	KR 83M	-0.0	PD 111	-0.0	MO 101	0.86042E 00
144	RB 87	-0.0	AG 113	-0.0	SM 155	0.83096E 00
145	Y 91M	-0.0	CD 113M	-0.0	RB 89	0.78222E 00
146	NB 93M	-0.0	CD 118	-0.0	SN 123	0.76814E 00
147	NB 95M	-0.0	IN 115	-0.0	GE 78	0.68988E 00
148	NB 97M	-0.0	IN 118	-0.0	LA 143	0.60916E 00
149	TC 99M	-0.0	IN 119	-0.0	PR 144	0.59913E 00
150	RH 103M	-0.0	SN 121	-0.0	BA 141	0.52613E 00
151	RH 105M	-0.0	SN 126	-0.0	IN 119	0.49832E 00
152	AG 109M	-0.0	SN 127	-0.0	PD 111	0.47915E 00

APPENDIX VI, continued

153	CD 117M	-0.0	SB 128	-0.0	RB 91	0.45252E 00
154	IN 115	-0.0	SB 129	-0.0	Y 95	0.42559E 00
155	TE 125M	-0.0	SB 131	-0.0	XE 135M	0.41642E 00
156	TE 127M	-0.0	TE 127	-0.0	TC 101	0.37172E 00
157	TE 129M	-0.0	TE 134	-0.0	ND 151	0.32593E 00
158	TE 131M	-0.0	XE 138	-0.0	U 239	0.32007E 00
159	TE 133M	-0.0	CS 135	-0.0	CD 118	0.29630E 00
160	XE 131M	-0.0	CS 137	-0.0	RH 107	0.29159E 00
161	XE 133M	-0.0	BA 141	-0.0	CE 146	0.26210E 00
162	XE 135M	-0.0	LA 143	-0.0	KR 83M	0.24349E 00
163	BA 137M	-0.0	PR 143	-0.0	SE 81	0.22963E 00
164	BE 7	-0.0	PR 145	-0.0	TE 133	0.16491E 00
165	FE 55	-0.0	ND 149	-0.0	RH 103M	0.11076E 00
166	MN 54	-0.0	PM 147	-0.0	MO 102	0.95996E-01
167	W 181	-0.0	SM 156	-0.0	BA 137M	0.88221E-01
168	PB 203	-0.0	H 3	-0.0	IN 118	0.64678E-01
169	PT 195M	-0.0	C 14	-0.0	XE 138	0.54546E-01
170	PU 238	-0.0	P 32	-0.0	NB 97M	0.38161E-01
171	BI 207	-0.0	S 35	-0.0	RH 106	0.23497E-01
172	TL 201	-0.0	C 136	-0.0	TC 102	0.14975E-01
173	PU 239	-0.0	CA 45	-0.0	RH 105M	0.50024E-02
174	PU 240	-0.0	W 185	-0.0	AG 109M	0.29462E-02
175	PB 204M	-0.0	TL 204	-0.0	RB 87	0.0
176	CR 51	-0.0	BI 210	-0.0	IN 115	0.0

APPENDIX VII

LISTING OF RADIONUCLIDES FOR ACCUMULATED SUBMERSION DOSES IN AIR CONTAINING INITIALLY 1 MICROCURIE PER GRAM

TIME 2600.

NO.	BETA DOSE NUCLIDE	BETA DOSE REMS	GAMMA DOSE NUCLIDE	GAMMA DOSE REMS	TOTAL DOSE NUCLIDE	TOTAL DOSE REMS
1	C 136	0.15675E 06	BI 207	0.20834E 06	BI 207	0.20834E 06
2	TC 99	0.64288E 05	CO 60	0.20009E 06	CO 60	0.20757E 06
3	SR 90	0.61048E 05	CS 134	0.55667E 05	C 136	0.15675E 06
4	CS 137	0.53794E 05	NA 22	0.51628E 05	TC 99	0.64288E 05
5	KR 85	0.35983E 05	I 129	0.20868E 05	SR 90	0.61048E 05
6	CS 135	0.30763E 05	SB 125	0.16280E 05	CS 134	0.60765E 05
7	C 14	0.26490E 05	PB 210	0.12588E 05	NA 22	0.59292E 05
8	SE 79	0.23378E 05	MN 54	0.10286E 05	CS 137	0.53794E 05
9	I 129	0.21403E 05	SM 151	0.84293E 04	I 129	0.42271E 05
10	CD 113M	0.14680E 05	PU 240	0.66256E 04	KR 85	0.40685E 05
11	TL 204	0.13891E 05	ZN 65	0.60236E 04	CS 135	0.30763E 05
12	PB 210	0.11490E 05	EU 155	0.49987E 04	C 14	0.26490E 05
13	PU 241	0.96868E 04	KR 85	0.47021E 04	PB 210	0.24078E 05
14	ZR 93	0.84972E 04	PU 239	0.42218E 04	SE 79	0.23378E 05
15	SM 151	0.84293E 04	FE 59	0.22135E 04	SB 125	0.19729E 05
16	NA 22	0.76647E 04	PU 238	0.20976E 04	SM 151	0.16859E 05
17	CO 60	0.74733E 04	NB 93M	0.18828E 04	CD 113M	0.14680E 05
18	PD 107	0.53120E 04	ZR 95	0.18699E 04	TL 204	0.13891E 05
19	CS 134	0.50975E 04	NB 95	0.10995E 04	PU 241	0.10625E 05
20	SB 125	0.34490E 04	PU 241	0.93864E 03	MN 54	0.10286E 05
21	PM 147	0.26765E 04	RU 103	0.81577E 03	ZR 93	0.84972E 04
22	Y 91	0.14694E 04	EU 156	0.77842E 03	PU 240	0.66256E 04
23	SR 89	0.12559E 04	CE 144	0.49764E 03	EU 155	0.61986E 04
24	EU 155	0.11999E 04	HG 203	0.49486E 03	ZN 65	0.60408E 04
25	H 3	0.97175E 03	TE 127M	0.33911E 03	PD 107	0.53120E 04
26	CE 144	0.95756E 03	W 181	0.28533E 03	PU 239	0.42218E 04
27	CA 45	0.53546E 03	TE 125M	0.26939E 03	PM 147	0.26765E 04
28	P 32	0.42245E 03	FE 55	0.26693E 03	FE 59	0.24330E 04
29	W 185	0.39854E 03	SC 48	0.26063E 03	ZR 95	0.21806E 04
30	SN 125	0.35918E 03	I 131	0.17669E 03	PU 238	0.20976E 04
31	ZR 95	0.31074E 03	LA 140	0.14894E 03	NB 93M	0.18828E 04
32	EU 156	0.30358E 03	TE 129M	0.14742E 03	Y 91	0.14784E 04
33	FE 59	0.21951E 03	CE 141	0.13081E 03	CE 144	0.14552E 04
34	CE 141	0.19951E 03	BE 7	0.12978E 03	SR 89	0.12559E 04
35	S 35	0.18434E 03	AU 196	0.12896E 03	NB 95	0.11644E 04
36	PR 143	0.18140E 03	BA 140	0.12829E 03	EU 156	0.10820E 04
37	BA 140	0.14521E 03	SB 127	0.11755E 03	H 3	0.97175E 03
38	RU 106	0.13826E 03	ND 147	0.11229E 03	RU 103	0.93354E 03
39	RU 103	0.11777E 03	NA 24	0.10883E 03	HG 203	0.60850E 03
40	HG 203	0.11364E 03	XE 131M	0.82467E 02	CA 45	0.53546E 03
41	AG 111	0.11170E 03	AU 198	0.47641E 02	P 32	0.42245E 03
42	ND 147	0.10674E 03	U 237	0.42931E 02	W 185	0.39854E 03
43	Y 90	0.98667E 02	SN 125	0.37639E 02	SN 125	0.39682E 03
44	BI 210	0.81447E 02	NB 95M	0.37113E 02	TE 127M	0.33911E 03
45	SB 127	0.70042E 02	PT 195M	0.35319E 02	CE 141	0.33031E 03
46	NB 95	0.64936E 02	CR 51	0.35047E 02	W 181	0.28533E 03
47	I 131	0.62361E 02	TE 132	0.31228E 02	SC 48	0.27764E 03
48	MO 99	0.47858E 02	W 187	0.29077E 02	BA 140	0.27350E 03
49	LA 140	0.38573E 02	PM 149	0.27056E 02	TE 125M	0.26939E 03
50	AU 198	0.36479E 02	PB 203	0.24363E 02	FE 55	0.26693E 03

APPENDIX VII, continued

51	PM 149	0.33891E 02	XE 133M	0.22563E 02	I 131	0.23905E 03
52	K 42	0.30094E 02	SB 126	0.20530E 02	ND 147	0.21903E 03
53	ZR 97	0.22730E 02	I 133	0.20267E 02	SB 127	0.18759E 03
54	XE 133	0.22234E 02	CE 143	0.18769E 02	LA 140	0.18751E 03
55	Y 93	0.21188E 02	XE 133	0.18010E 02	S 35	0.18434E 03
56	CE 143	0.20857E 02	I 135	0.17951E 02	PR 143	0.18140E 03
57	RH 105	0.19133E 02	NP 239	0.17705E 02	TE 129M	0.14742E 03
58	U 237	0.18458E 02	SR 91	0.14365E 02	RU 106	0.13826E 03
59	PM 151	0.18250E 02	MO 99	0.14035E 02	AU 196	0.13006E 03
60	I 133	0.17922E 02	PM 151	0.12463E 02	BE 7	0.12978E 03
61	ZN 65	0.17148E 02	SM 153	0.12284E 02	NA 24	0.12362E 03
62	SM 153	0.17122E 02	Y 93	0.12258E 02	AG 111	0.12115E 03
63	SC 48	0.17014E 02	AG 111	0.94470E 01	Y 90	0.99302E 02
64	SB 129	0.14786E 02	Y 91	0.89634E 01	AU 198	0.84120E 02
65	NA 24	0.14786E 02	I 132	0.84532E 01	XE 131M	0.82467E 02
66	NP 239	0.12284E 02	K 42	0.65848E 01	BI 210	0.81447E 02
67	W 187	0.11597E 02	KR 88	0.63114E 01	MO 99	0.61893E 02
68	SR 91	0.10488E 02	RU 105	0.57327E 01	U 237	0.61389E 02
69	EU 152	0.95054E 01	XE 135	0.42878E 01	PM 149	0.60947E 02
70	Y 92	0.86872E 01	PB 204M	0.40721E 01	W 187	0.40674E 02
71	TE 132	0.82463E 01	CD 117M	0.40089E 01	XE 133	0.40244E 02
72	PD 109	0.77827E 01	AG 112	0.36716E 01	CE 143	0.39626E 02
73	AG 112	0.73695E 01	EU 152	0.36418E 01	TE 132	0.39474E 02
74	PR 145	0.66540E 01	BA 139	0.33486E 01	I 133	0.38189E 02
75	AG 113	0.64241E 01	Y 92	0.26917E 01	NB 95M	0.37113E 02
76	LA 141	0.61129E 01	AS 78	0.26912E 01	K 42	0.36679E 02
77	SM 156	0.59888E 01	KR 87	0.26261E 01	PT 195M	0.35319E 02
78	SN 127	0.55183E 01	IN 115M	0.24866E 01	CR 51	0.35047E 02
79	SN 121	0.55040E 01	TE 129	0.23235E 01	Y 93	0.33446E 02
80	SB 126	0.54643E 01	TL 201	0.20934E 01	PM 151	0.30713E 02
81	XE 135	0.49461E 01	RH 105	0.20650E 01	NP 239	0.29989E 02
82	SB 128	0.47122E 01	I 134	0.19448E 01	SM 153	0.29407E 02
83	I 135	0.37457E 01	CS 138	0.18804E 01	SB 126	0.25995E 02
84	TE 127	0.37062E 01	SE 83	0.15204E 01	SR 91	0.24853E 02
85	AS 78	0.33317E 01	TC 99M	0.14938E 01	PB 203	0.24363E 02
86	RU 105	0.32454E 01	LA 142	0.14168E 01	ZR 97	0.22730E 02
87	KR 87	0.29777E 01	NB 97	0.14047E 01	XE 133M	0.22563E 02
88	CU 64	0.25896E 01	IN 117	0.14021E 01	I 135	0.21696E 02
89	LA 142	0.21664E 01	KR 85M	0.13840E 01	RH 105	0.21198E 02
90	SR 92	0.20856E 01	BR 84	0.13236E 01	SB 129	0.14786E 02
91	TE 134	0.20817E 01	CD 117	0.12604E 01	EU 152	0.13147E 02
92	PD 112	0.20270E 01	TE 131M	0.93177E 00	Y 92	0.11379E 02
93	I 132	0.19760E 01	Y 91M	0.82397E 00	AG 112	0.11041E 02
94	BA 139	0.19222E 01	MN 56	0.82070E 00	I 132	0.10429E 02
95	KR 88	0.19144E 01	PR 146	0.79789E 00	XE 135	0.92339E 01
96	ND 149	0.18951E 01	TE 133M	0.73872E 00	RU 105	0.89781E 01
97	KR 85M	0.18025E 01	Y 94	0.67593E 00	KR 88	0.82258E 01
98	IN 117M	0.17177E 01	PD 112	0.66339E 00	PD 109	0.77827E 01
99	RH 109	0.16933E 01	IN 117M	0.64916E 00	PR 145	0.66540E 01
100	SN 126	0.15069E 01	Y 90	0.63510E 00	LA 141	0.66003E 01
101	TE 129	0.14511E 01	LA 141	0.48745E 00	AG 113	0.64241E 01

APPENDIX VII, continued

102	SB 131	0.14317E 01	MO 101	0.36873E 00	AS 78	0.60230E 01
103	BR 83	0.14201E 01	TE 131	0.34449E 00	SM 156	0.59888E 01
104	CS 138	0.12453E 01	RB 88	0.31370E 00	KR 87	0.56038E 01
105	BR 84	0.11948E 01	SM 155	0.24160E 00	SN 127	0.55183E 01
106	Y 94	0.11636E 01	XE 135M	0.23749E 00	SN 121	0.55040E 01
107	AU 196	0.11068E 01	BR 83	0.21491E 00	BA 139	0.52708E 01
108	RB 88	0.10962E 01	SN 123	0.17708E 00	SB 128	0.47122E 01
109	I 134	0.10634E 01	KR 83M	0.13887E 00	PB 204M	0.40721E 01
110	NB 97	0.98854E 00	TC 101	0.12290E 00	CD 117M	0.40089E 01
111	RB 89	0.89222E 00	CE 146	0.10372E 00	TE 129	0.37746E 01
112	PR 146	0.88993E 00	TE 133	0.76012E-01	TE 127	0.37062E 01
113	GE 78	0.78690E 00	CU 64	0.71448E-01	LA 142	0.35833E 01
114	LA 143	0.69482E 00	RH 103M	0.63171E-01	KR 85M	0.31865E 01
115	PR 144	0.60222E 00	BA 137M	0.50314E-01	CS 138	0.31257E 01
116	BA 141	0.60012E 00	U 239	0.44942E-01	I 134	0.30082E 01
117	IN 119	0.56839E 00	PR 144	0.40581E-01	PD 112	0.26904E 01
118	PD 111	0.54653E 00	ND 151	0.25676E-01	CU 64	0.26611E 01
119	CD 117	0.52403E 00	NB 97M	0.21764E-01	IN 115M	0.26197E 01
120	SN 123	0.52199E 00	RH 106	0.36065E-02	BR 84	0.25184E 01
121	RB 91	0.51616E 00	RH 105M	0.28529E-02	NB 97	0.23932E 01
122	Y 95	0.48544E 00	AG 109M	0.16803E-02	IN 117M	0.23669E 01
123	TE 131	0.47855E 00	GE 78	-0.0	TL 201	0.20934E 01
124	IN 117	0.46735E 00	SE 79	-0.0	SR 92	0.20856E 01
125	SM 155	0.46461E 00	SE 81	-0.0	TE 134	0.20817E 01
126	MN 56	0.39585E 00	RB 87	-0.0	ND 149	0.18951E 01
127	SE 83	0.34147E 00	RB 89	-0.0	IN 117	0.18694E 01
128	CD 118	0.33796E 00	RB 91	-0.0	SE 83	0.18619E 01
129	RH 107	0.33260E 00	SR 89	-0.0	Y 94	0.18395E 01
130	ND 151	0.32041E 00	SR 90	-0.0	CD 117	0.17844E 01
131	U 239	0.27520E 00	SR 92	-0.0	RH 109	0.16933E 01
132	SE 81	0.26192E 00	Y 95	-0.0	PR 146	0.16878E 01
133	MO 101	0.24397E 00	ZR 93	-0.0	BR 83	0.16350E 01
134	TC 101	0.17820E 00	ZR 97	-0.0	SN 126	0.15069E 01
135	IN 115M	0.13313E 00	MO 102	-0.0	TC 99M	0.14938E 01
136	MO 102	0.10950E 00	TC 99	-0.0	SB 131	0.14317E 01
137	CE 146	0.91506E-01	TC 102	-0.0	RB 88	0.14099E 01
138	IN 118	0.73773E-01	RU 106	-0.0	MN 56	0.12166E 01
139	XE 138	0.62217E-01	RH 107	-0.0	TE 131M	0.93177E 00
140	TE 133	0.36071E-01	RH 109	-0.0	RB 89	0.89222E 00
141	RH 106	0.19589E-01	PD 107	-0.0	Y 91M	0.82397E 00
142	TC 102	0.17081E-01	PD 109	-0.0	TE 131	0.82304E 00
143	KR 83M	-0.0	PD 111	-0.0	GE 78	0.78690E 00
144	RB 87	-0.0	AG 113	-0.0	TE 133M	0.73872E 00
145	Y 91M	-0.0	CD 113M	-0.0	SM 155	0.70621E 00
146	NB 93M	-0.0	CD 118	-0.0	SN 123	0.69907E 00
147	NB 95M	-0.0	IN 115	-0.0	LA 143	0.69482E 00
148	NB 97M	-0.0	IN 118	-0.0	PR 144	0.64280E 00
149	TC 99M	-0.0	IN 119	-0.0	MO 101	0.61269E 00
150	RH 103M	-0.0	SN 121	-0.0	BA 141	0.60012E 00
151	RH 105M	-0.0	SN 126	-0.0	IN 119	0.56839E 00
152	AG 109M	-0.0	SN 127	-0.0	PD 111	0.54653E 00

APPENDIX VII, continued

153	CD 117M	-0.0	SB 128	-0.0	RB 91	0.51616E 00
154	IN 115	-0.0	SB 129	-0.0	Y 95	0.48544E 00
155	TE 125M	-0.0	SB 131	-0.0	ND 151	0.34608E 00
156	TE 127M	-0.0	TE 127	-0.0	CD 118	0.33796E 00
157	TE 129M	-0.0	TE 134	-0.0	RH 107	0.33260E 00
158	TE 131M	-0.0	XE 138	-0.0	U 239	0.32014E 00
159	TE 133M	-0.0	CS 135	-0.0	TC 101	0.30109E 00
160	XE 131M	-0.0	CS 137	-0.0	SE 81	0.26192E 00
161	XE 133M	-0.0	BA 141	-0.0	XE 135M	0.23749E 00
162	XE 135M	-0.0	LA 143	-0.0	CE 146	0.19523E 00
163	BA 137M	-0.0	PR 143	-0.0	KR 83M	0.13887E 00
164	BE 7	-0.0	PR 145	-0.0	TE 133	0.11208E 00
165	FE 55	-0.0	ND 149	-0.0	MO 102	0.10950E 00
166	MN 54	-0.0	PM 147	-0.0	IN 118	0.73773E-01
167	W 181	-0.0	SM 156	-0.0	RH 103M	0.63171E-01
168	PB 203	-0.0	H 3	-0.0	XE 138	0.62217E-01
169	PT 195M	-0.0	C 14	-0.0	BA 137M	0.50314E-01
170	PU 238	-0.0	P 32	-0.0	RH 106	0.23195E-01
171	BI 207	-0.0	S 35	-0.0	NB 97M	0.21764E-01
172	TL 201	-0.0	C 136	-0.0	TC 102	0.17081E-01
173	PU 239	-0.0	CA 45	-0.0	RH 105M	0.28529E-02
174	PU 240	-0.0	W 185	-0.0	AG 109M	0.16803E-02
175	PB 204M	-0.0	TL 204	-0.0	RB 87	0.0
176	CR 51	-0.0	BI 210	-0.0	IN 115	0.0

APPENDIX VIII

LISTING OF RADIONUCLIDES FOR ACCUMULATED DOSES ABOVE GROUND SURFACE CONTAMINATED INITIALLY WITH 1 MICROCURIE PER SQ CM

DISTANCE= 0.760000E 02

TIME 2600.TAU 0

	BETA DOSE		GAMMA DOSE		TOTAL DOSE	
NO.	NUCLIDE	REMS	NUCLIDE	REMS	NUCLIDE	REMS
1	C 136	0.15814E 06	BI 207	0.30661E 05	C 136	0.15814E 06
2	SR 90	0.56249E 05	CO 60	0.27951E 05	SR 90	0.56249E 05
3	CS 137	0.35160E 05	CS 134	0.83881E 04	CS 137	0.35160E 05
4	KR 85	0.33367E 05	NA 22	0.71506E 04	KR 85	0.34093E 05
5	TL 204	0.17019E 05	I 129	0.70203E 04	BI 207	0.30661E 05
6	PM 147	0.73342E 04	PU 238	0.34473E 04	CO 60	0.27964E 05
7	CD 113M	0.72607E 04	PB 210	0.32203E 04	TL 204	0.17019E 05
8	Y 91	0.43911E 04	SB 125	0.22954E 04	CS 134	0.12098E 05
9	CS 134	0.37098E 04	SM 151	0.22474E 04	NA 22	0.96981E 04
10	SR 89	0.33450E 04	MN 54	0.15463E 04	PM 147	0.73342E 04
11	NA 22	0.25475E 04	PU 240	0.15223E 04	CD 113M	0.72607E 04
12	P 32	0.12559E 04	NB 93M	0.11298E 04	I 129	0.70203E 04
13	SN 125	0.94997E 03	ZN 65	0.10597E 04	Y 91	0.43923E 04
14	SB 125	0.70553E 03	PU 239	0.88644E 03	PU 238	0.34473E 04
15	EU 156	0.66056E 03	KR 85	0.72666E 03	SR 89	0.33450E 04
16	PR 143	0.33466E 03	FE 59	0.31666E 03	PB 210	0.32203E 04
17	Y 90	0.27135E 03	ZR 95	0.28675E 03	SB 125	0.30009E 04
18	BA 140	0.24267E 03	NB 95	0.16816E 03	SM 151	0.22474E 04
19	AG 111	0.23180E 03	RU 103	0.12607E 03	MN 54	0.15463E 04
20	BI 210	0.19520E 03	PU 241	0.11664E 03	PU 240	0.15223E 04
21	SB 127	0.17094E 03	EU 156	0.96733E 02	P 32	0.12559E 04
22	ND 147	0.12636E 03	FE 55	0.87121E 02	NB 93M	0.11298E 04
23	MO 99	0.11360E 03	CE 144	0.84668E 02	ZN 65	0.10597E 04
24	LA 140	0.10379E 03	HG 203	0.73417E 02	SN 125	0.95474E 03
25	PM 149	0.73434E 02	TE 127M	0.44208E 02	PU 239	0.88644E 03
26	AU 198	0.70454E 02	SC 48	0.37276E 02	EU 156	0.75729E 03
27	ZR 97	0.65990E 02	W 181	0.35974E 02	FE 59	0.34247E 03
28	K 42	0.65158E 02	TE 125M	0.33477E 02	PR 143	0.33466E 03
29	Y 93	0.48131E 02	I 131	0.26911E 02	ZR 95	0.30790E 03
30	I 133	0.46340E 02	BA 14C	0.26119E 02	Y 90	0.27144E 03
31	CE 141	0.46054E 02	LA 140	0.20270E 02	BA 140	0.26879E 03
32	CE 143	0.45247E 02	BE 7	0.20147E 02	AG 111	0.23324E 03
33	PM 151	0.41495E 02	AU 196	0.19835E 02	BI 210	0.19520E 03
34	NA 24	0.38834E 02	TE 129M	0.18320E 02	SB 127	0.18892E 03
35	I 131	0.33648E 02	SB 127	0.17979E 02	NB 95	0.16816E 03
36	TC 99	0.32480E 02	CE 141	0.17140E 02	RU 103	0.14439E 03
37	RH 105	0.31336E 02	ND 147	0.16565E 02	ND 147	0.14292E 03
38	EU 152	0.27718E 02	NA 24	0.13453E 02	LA 140	0.12406E 03
39	FE 59	0.25812E 02	XE 131M	0.11000E 02	PU 241	0.11664E 03
40	SB 129	0.25779E 02	U 237	0.81380E 01	MO 99	0.11540E 03
41	SR 91	0.25627E 02	AU 198	0.73293E 01	FE 55	0.87121E 02
42	W 185	0.23169E 02	PT 195M	0.54910E 01	CE 144	0.85320E 02
43	ZR 95	0.21153E 02	NB 95M	0.53796E 01	AU 198	0.77784E 02
44	PR 145	0.19796E 02	CR 51	0.52937E 01	PM 149	0.77468E 02
45	W 187	0.18785E 02	SN 125	0.47742E 01	HG 203	0.73417E 02
46	AG 113	0.18381E 02	TE 132	0.45266E 01	K 42	0.66036E 02
47	RU 103	0.18319E 02	W 187	0.44661E 01	ZR 97	0.65990E 02
48	Y 92	0.18307E 02	PM 149	0.40340E 01	CE 141	0.63193E 02
49	SM 153	0.16169E 02	NP 239	0.37475E 01	I 131	0.60559E 02
50	LA 141	0.15979E 02	XE 133M	0.32706E 01	NA 24	0.52287E 02

APPENDIX VIII, continued

51	AG 112	0.15270E 02	I 133	0.31141E 01	Y 93	0.50011E 02
52	PD 109	0.15046E 02	PB 203	0.31013E 01	SC 48	0.49792E 02
53	CO 60	0.13347E 02	SB 126	0.30900E 01	I 133	0.49454E 02
54	SC 48	0.12517E 02	CE 143	0.28151E 01	CE 143	0.48063E 02
55	SB 126	0.11161E 02	XE 133	0.24491E 01	TE 127M	0.44208E 02
56	SM 156	0.10421E 02	I 135	0.23398E 01	PM 151	0.43314E 02
57	SN 127	0.89265E 01	SR 91	0.21406E 01	W 181	0.35974E 02
58	XE 135	0.85760E 01	Y 93	0.18798E 01	TE 125M	0.33477E 02
59	RU 105	0.76739E 01	PM 151	0.18195E 01	TC 99	0.32480E 02
60	I 135	0.73737E [illegible]	MO 99	0.17984E 01	RH 105	0.31648E 02
61	AS 78	0.71206E [illegible]	SM 153	0.17144E 01	EU 152	0.28185E 02
62	SB 128	0.66417E 01	AG 111	0.14390E 01	SR 91	0.27768E 02
63	KR 87	0.61846E 01	Y 91	0.12691E 01	SB 129	0.25779E 02
64	ND 149	0.56455E 01	I 132	0.12629E 01	W 187	0.23251E 02
65	LA 142	0.56092E 01	PD 112	0.96111E 00	W 185	0.23169E 02
66	IN 117M	0.50928E 01	K 42	0.87830E 00	BE 7	0.20147E 02
67	BA 139	0.50694E 01	RU 105	0.87677E 00	AU 196	0.19835E 02
68	I 132	0.49334E 01	KR 88	0.86549E 00	PR 145	0.19796E 02
69	SR 92	0.48962E 01	XE 135	0.63263E 00	Y 92	0.18685E 02
70	RH 109	0.44887E 01	PB 204M	0.61144E 00	AG 113	0.18381E 02
71	TE 129	0.42759E 01	CD 117M	0.60588E 00	TE 129M	0.18320E 02
72	TE 134	0.40873E 01	AG 112	0.50902E 00	SM 153	0.17883E 02
73	SN 126	0.38597E 01	EU 152	0.46660E 00	LA 141	0.16044E 02
74	TE 127	0.35163E 01	BA 139	0.44927E 00	AG 112	0.15779E 02
75	KR 88	0.33101E 01	AS 78	0.39142E 00	PD 109	0.15046E 02
76	I 134	0.29863E 01	Y 92	0.37876E 00	SB 126	0.14251E 02
77	CS 138	0.28556E 01	IN 115M	0.37580E 00	XE 131M	0.11000E 02
78	KR 85M	0.27140E 01	TE 129	0.34982E 00	SM 156	0.10421E 02
79	BR 83	0.26554E 01	KR 87	0.33253E 00	I 135	0.97135E 01
80	NB 97	0.24931E 01	RH 105	0.31183E 00	XE 135	0.92086E 01
81	BR 84	0.24391E 01	TL 201	0.27922E 00	SN 127	0.89265E 01
82	NP 239	0.23308E 01	I 134	0.26369E 00	RU 105	0.85506E 01
83	SB 131	0.20958E 01	CS 138	0.26220E 00	U 237	0.81384E 01
84	PR 146	0.19110E 01	LA 142	0.21855E 00	AS 78	0.75120E 01
85	RB 88	0.17518E 01	SE 83	0.21819E 00	SB 128	0.66417E 01
86	Y 94	0.17142E 01	NB 97	0.21773E 00	KR 87	0.65172E 01
87	LA 143	0.15955E 01	IN 117	0.20916E 00	I 132	0.61963E 01
88	RB 89	0.15330E 01	TC 99M	0.19169E 00	NP 239	0.60783E 01
89	PD 111	0.15273E 01	KR 85M	0.18969E 00	LA 142	0.58278E 01
90	BA 141	0.14553E 01	BR 84	0.17527E 00	ND 149	0.56455E 01
91	IN 119	0.14089E 01	CD 117	0.17506E 00	BA 139	0.55186E 01
92	PR 144	0.14034E 01	CU 64	0.15173E 00	PT 195M	0.54910E 01
93	CU 64	0.13818E 01	KR 83M	0.14131E 00	NB 95M	0.53796E 01
94	GE 78	0.13693E 01	Y 91M	0.12733E 00	CR 51	0.52937E 01
95	SM 155	0.13690E 01	TE 131M	0.12617E 00	IN 117M	0.51833E 01
96	TE 131	0.13308E 01	PR 146	0.11600E 00	SR 92	0.48962E 01
97	SN 123	0.13125E 01	TE 133M	0.11377E 00	TE 129	0.46257E 01
98	RB 91	0.11982E 01	MN 56	0.11212E 00	TE 132	0.45266E 01
99	CD 117	0.10250E 01	Y 94	0.91524E-01	RH 109	0.44887E 01
100	Y 95	0.98038E 00	IN 117M	0.90547E-01	KR 88	0.41756E 01
101	ND 151	0.92735E 00	Y 90	0.85996E-01	TE 134	0.40873E 01

APPENDIX VIII, continued

102	MN 56	0.91544E 00	LA 141	0.64551E-01	SN 126	0.38597E 01
103	RH 107	0.81172E 00	MO 101	0.53236E-01	TE 127	0.35163E 01
104	CD 118	0.76164E 00	TE 131	0.49984E-01	XE 133M	0.32706E 01
105	SE 83	0.72922E 00	BR 83	0.47859E-01	I 134	0.32499E 01
106	SE 81	0.68586E 00	RB 88	0.41151E-01	CS 138	0.31178E 01
107	U 239	0.67536E 00	XE 135M	0.36673E-01	PB 203	0.31013E 01
108	CE 144	0.65271E 00	SM 155	0.33783E-01	KR 85M	0.29037E 01
109	MO 101	0.63131E 00	SN 123	0.23451E-01	NB 97	0.27109E 01
110	IN 117	0.52341E 00	RH 103M	0.21301E-01	BR 83	0.27033E 01
111	TC 101	0.43490E 00	TC 101	0.18356E-01	BR 84	0.26144E 01
112	IN 118	0.21977E 00	CE 146	0.14558E-01	XE 133	0.25912E 01
113	IN 115M	0.19791E 00	TE 133	0.11445E-01	SB 131	0.20958E 01
114	MO 102	0.19780E 00	U 239	0.87904E-02	PR 146	0.20270E 01
115	XE 133	0.14209E 00	BA 137M	0.77488E-02	Y 94	0.18057E 01
116	SN 121	0.11440E 00	PR 144	0.55330E-02	RB 88	0.17930E 01
117	TE 133	0.93683E-01	NB 97M	0.33196E-02	LA 143	0.15955E 01
118	CE 146	0.86818E-01	RH 106	0.54929E-03	CU 64	0.15335E 01
119	ZN 65	0.50088E-01	RH 105M	0.36072E-03	RB 89	0.15330E 01
120	RH 106	0.42249E-01	AG 109M	0.21905E-03	PD 111	0.15273E 01
121	TC 102	0.37097E-01	GE 78	-0.0	BA 141	0.14553E 01
122	CA 45	0.24642E-01	SE 79	-0.0	IN 119	0.14089E 01
123	EU 155	0.97081E-02	SE 81	-0.0	PR 144	0.14089E 01
124	CS 135	0.79884E-02	RB 87	-0.0	SM 155	0.14028E 01
125	U 237	0.41993E-03	RB 89	-0.0	TE 131	0.13808E 01
126	AU 196	0.65282E-04	RB 91	-0.0	GE 78	0.13693E 01
127	XE 138	0.61245E-04	SR 89	-0.0	SN 123	0.13360E 01
128	HG 203	0.39642E-04	SR 90	-0.0	CD 117	0.12001E 01
129	TE 132	0.86659E-05	SR 92	-0.0	RB 91	0.11982E 01
130	PD 112	0.10534E-06	Y 95	-0.0	MN 56	0.10276E 01
131	SE 79	0.52088E-07	ZR 93	-0.0	Y 95	0.98038E 00
132	C 14	0.14305E-07	ZR 97	-0.0	PD 112	0.96111E 00
133	S 35	0.38243E-08	MO 102	-0.0	SE 83	0.94741E 00
134	I 129	0.10991E-08	TC 99	-0.0	ND 151	0.92735E 00
135	NB 95	0.14468E-09	TC 102	-0.0	RH 107	0.81172E 00
136	SM 151	0.44654E-58	RU 106	-0.0	CD 118	0.76164E 00
137	KR 83M	-0.0	RH 107	-0.0	IN 117	0.73256E 00
138	RB 87	-0.0	RH 109	-0.0	SE 81	0.68586E 00
139	Y 91M	-0.0	PD 107	-0.0	MO 101	0.68455E 00
140	ZR 93	-0.0	PD 109	-0.0	U 239	0.68415E 00
141	NB 93M	-0.0	PD 111	-0.0	PB 204M	0.61144E 00
142	NB 95M	-0.0	AG 113	-0.0	CD 117M	0.60588E 00
143	NB 97M	-0.0	CD 113M	-0.0	IN 115M	0.57371E 00
144	TC 99M	-0.0	CD 118	-0.0	TC 101	0.45326E 00
145	RU 106	-0.0	IN 115	-0.0	TL 201	0.27922E 00
146	RH 103M	-0.0	IN 118	-0.0	IN 118	0.21977E 00
147	RH 105M	-0.0	IN 119	-0.0	MO 102	0.19780E 00
148	PD 107	-0.0	SN 121	-0.0	TC 99M	0.19169E 00
149	AG 109M	-0.0	SN 126	-0.0	KR 83M	0.14131E 00
150	CD 117M	-0.0	SN 127	-0.0	Y 91M	0.12733E 00
151	IN 115	-0.0	SB 128	-0.0	TE 131M	0.12617E 00
152	TE 125M	-0.0	SB 129	-0.0	SN 121	0.11440E 00

APPENDIX VIII, continued

153	TE 127M	-0.0	SB 131	-0.0	TE 133M	0.11377E 00
154	TE 129M	-0.0	TE 127	-0.0	TE 133	0.10513E 00
155	TE 131M	-0.0	TE 134	-0.0	CE 146	0.10138E 00
156	TE 133M	-0.0	XE 138	-0.0	RH 106	0.42799E-01
157	XE 131M	-0.0	CS 135	-0.0	TC 102	0.37097E-01
158	XE 133M	-0.0	CS 137	-0.0	XE 135M	0.36673E-01
159	XE 135M	-0.0	BA 141	-0.0	CA 45	0.24642E-01
160	BA 137M	-0.0	LA 143	-0.0	RH 103M	0.21301E-01
161	H 3	-0.0	PR 143	-0.0	EU 155	0.97081E-02
162	BE 7	-0.0	PR 145	-0.0	CS 135	0.79884E-02
163	FE 55	-0.0	ND 149	-0.0	BA 137M	0.77488E-02
164	MN 54	-0.0	ND 151	-0.0	NB 97M	0.33196E-02
165	W 181	-0.0	PM 147	-0.0	RH 105M	0.36072E-03
166	PB 203	-0.0	SM 156	-0.0	AG 109M	0.21905E-03
167	PT 195M	-0.0	EU 155	-0.0	XE 138	0.61245E-04
168	PU 238	-0.0	H 3	-0.0	SE 79	0.52088E-07
169	BI 207	-0.0	C 14	-0.0	C 14	0.14305E-07
170	TL 201	-0.0	P 32	-0.0	S 35	0.38243E-08
171	PU 239	-0.0	S 35	-0.0	RB 87	0.0
172	PU 240	-0.0	C 136	-0.0	ZR 93	0.0
173	PU 241	-0.0	CA 45	-0.0	RU 106	0.0
174	PB 210	-0.0	W 185	-0.0	PD 107	0.0
175	PB 204M	-0.0	TL 204	-0.0	IN 115	0.0
176	CR 51	-0.0	BI 210	-0.0	H 3	0.0

APPENDIX IX

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5   TAU = 0.   T = 25550.   ORGAN = TOTAL BODY

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
1	PU-239	0.2176467E 03	SR-90	0.1908106E 01
2	PU-240	0.2171915E 03	PB-210	0.5301245E 00
3	PU-238	0.1840500E 03	CS-134	0.7592928E-01
4	PU-241	0.2694068E 01	CS-137	0.4385849E-01
5	SR-90	0.2544142E 01	PU-239	0.2611759E-01
6	PB-210	0.1921701E 01	PU-240	0.2606297E-01
7	EU-152	0.9794879E-01	PU-238	0.2208599E-01
8	CE-144	0.6592041E-01	NA-22	0.1869029E-01
9	CS-134	0.5694696E-01	I-129	0.1304285E-01
10	CS-137	0.3289387E-01	CA-45	0.8877035E-02
11	ZN-65	0.1977771E-01	SR-89	0.8813635E-02
12	ZR-95	0.1620798E-01	CL-36	0.8007091E-02
13	NA-22	0.1401772E-01	CS-136	0.7592931E-02
14	EU-155	0.1333808E-01	P-32	0.7419035E-02
15	SR-89	0.1175152E-01	ZN-65	0.6592568E-02
16	FE-59	0.1101888E-01	CS-135	0.4906204E-02
17	I-129	0.9782135E-02	CO-60	0.4539829E-02
18	Y-91	0.9084973E-02	RB-87	0.4300892E-02
19	CA-45	0.8137282E-02	FE-59	0.3672960E-02
20	BA-140	0.7317673E-02	I-131	0.3551156E-02
21	SM-151	0.7192045E-02	TE-129M	0.2920358E-02
22	PM-147	0.7016025E-02	S-35	0.2634482E-02
23	NB-93M	0.6355762E-02	NA-24	0.1720357E-02
24	P-32	0.6231990E-02	HG-203	0.1632747E-02
25	CO-60	0.6053109E-02	TE-132	0.1311506E-02
26	CL-36	0.6005317E-02	BA-140	0.1306728E-02
27	CS-136	0.5694699E-02	TE-127M	0.1104427E-02
28	CD-115M	0.5668148E-02	K-42	0.8835411E-03
29	NB-95	0.4535846E-02	MN-54	0.8773815E-03
30	TE-129M	0.4438940E-02	MO-99	0.8257707E-03
31	SB-125	0.3715969E-02	I-133	0.7760720E-03
32	CS-135	0.3679653E-02	TL-204	0.5973463E-03
33	RB-87	0.3225669E-02	C-14	0.5734523E-03
34	RU-106	0.2890198E-02	TE-131M	0.4884962E-03
35	I-131	0.2663367E-02	TE-125M	0.4778770E-03
36	MN-54	0.2632145E-02	SB-125	0.4128853E-03
37	ZR-93	0.2628322E-02	I-135	0.3865489E-03
38	IN-115	0.2166375E-02	SN-125	0.3743365E-03
39	SN-125	0.2096285E-02	PU-241	0.3232881E-03
40	TE-132	0.1993489E-02	RU-106	0.3211331E-03
41	S-35	0.1975861E-02	FE-55	0.3195934E-03
42	TE-127M	0.1678728E-02	SR-91	0.2676109E-03
43	CE-141	0.1672569E-02	AU-196	0.2637878E-03
44	BI-207	0.1380534E-02	I-132	0.1751153E-03
45	HG-203	0.1371507E-02	AU-198	0.1601418E-03
46	NA-24	0.1290268E-02	TL-201	0.1543540E-03
47	ND-147	0.1178763E-02	H-3	0.1274339E-03
48	PR-143	0.1146904E-02	SR-92	0.9111511E-04
49	SC-48	0.9929221E-03	RU-103	0.8690984E-04
50	FE-55	0.9587801E-03	I-134	0.5734524E-04
51	LA-140	0.8474349E-03	CD-115M	0.5668150E-04

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = TOTAL BODY

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
52	AU-196	0.7913639E-03	RH-105	0.5649564E-04
53	RU-103	0.7821887E-03	BI-207	0.5309744E-04
54	TE-131M	0.7425142E-03	TC-99	0.4991160E-04
55	TE-125M	0.7263729E-03	PD-109	0.4549386E-04
56	MO-99	0.6709388E-03	PB-203	0.4055790E-04
57	K-42	0.6626558E-03	CU-64	0.3939829E-04
58	TL-204	0.6371692E-03	EU-152	0.3917952E-04
59	Y-90	0.6332397E-03	W-187	0.3610624E-04
60	I-133	0.5820540E-03	CE-144	0.2636816E-04
61	AU-198	0.4804253E-03	TE-127	0.2421242E-04
62	C-14	0.4300892E-03	MN-56	0.2219471E-04
63	CD-115	0.4146909E-03	W-181	0.2123897E-04
64	ZR-97	0.3958412E-03	IN-115	0.1733098E-04
65	BE-7	0.3809740E-03	W-185	0.1486728E-04
66	SR-91	0.3568146E-03	TE-129	0.1326905E-04
67	CE-143	0.3425048E-03	AG-111	0.1274338E-04
68	AG-111	0.3313280E-03	AS-77	0.1223364E-04
69	PM-149	0.3153987E-03	RU-105	0.7263729E-05
70	I-135	0.2899116E-03	ZR-95	0.6483190E-05
71	Y-93	0.1895578E-03	PB-204M	0.5350517E-05
72	NP-239	0.1793897E-03	EU-155	0.5335231E-05
73	CR-51	0.1765489E-03	CD-115	0.4146909E-05
74	TL-201	0.1646443E-03	Y-91	0.3633989E-05
75	SM-153	0.1553100E-03	CR-51	0.3530977E-05
76	PB-203	0.1470225E-03	BE-7	0.3047791E-05
77	I-132	0.1313364E-03	SM-151	0.2876818E-05
78	H-3	0.1274339E-03	PM-147	0.2806410E-05
79	SR-92	0.1214868E-03	NB-93M	0.2542305E-05
80	AS-77	0.1101027E-03	NB-95	0.1814338E-05
81	W-187	0.1083188E-03	TC-99M	0.1529205E-05
82	RH-105	0.9886739E-04	ZR-93	0.1051329E-05
83	PD-109	0.7961424E-04	CE-141	0.6690274E-06
84	GD-159	0.7168151E-04	ND-147	0.4715051E-06
85	MN-56	0.6658415E-04	PR-143	0.4587616E-06
86	RU-105	0.6537356E-04	RH-103M	0.4438943E-06
87	W-181	0.6371693E-04	SC-48	0.3971688E-06
88	Y-92	0.6371690E-04	LA-140	0.3389739E-06
89	CU-64	0.5487620E-04	Y-90	0.2532959E-06
90	TC-99	0.4991160E-04	ZR-97	0.1583365E-06
91	W-185	0.4460184E-04	CE-143	0.1370020E-06
92	I-134	0.4300893E-04	PM-149	0.1261595E-06
93	TE-127	0.3680289E-04	IN-115M	0.1049205E-06
94	ND-149	0.2423895E-04	Y-93	0.7582310E-07
95	TE-129	0.2016894E-04	NP-239	0.7175584E-07
96	PB-204M	0.1939562E-04	SM-153	0.6212400E-07
97	IN-115M	0.1311507E-04	GD-159	0.2867260E-07
98	NB-97	0.1177966E-04	Y-92	0.2548676E-07
99	Y-91M	0.8641608E-05	ND-149	0.9695579E-08
100	TC-99M	0.1529205E-05	NB-97	0.4711861E-08
101	RH-103M	0.7768150E-06	Y-91M	0.3456643E-08

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = BONE

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
1	PU-239	0.1019287E 05	SR-90	0.3569995E 02
2	PU-240	0.1017596E 05	PB-210	0.1672836E 02
3	PU-238	0.8315762E 04	PU-239	0.1223145E 01
4	PU-241	0.1485529E 03	PU-240	0.1221115E 01
5	PB-210	0.6691344E 02	PU-238	0.9978915E 00
6	SR-90	0.4759991E 02	CA-45	0.4523378E 00
7	CE-144	0.1380680E 01	ZN-65	0.3001530E 00
8	EU-152	0.5537338E 00	P-32	0.2225381E 00
9	CA-45	0.4188313E 00	SR-89	0.1527271E 00
10	Y-91	0.3842953E 00	CS-137	0.9292930E-01
11	PM-147	0.2159090E 00	CS-134	0.5714286E-01
12	SR-89	0.2036362E 00	CS-135	0.2222222E-01
13	SM-151	0.2028778E 00	BA-140	0.1891415E-01
14	P-32	0.1898991E 00	NA-22	0.1869029E-01
15	EU-155	0.1330303E 00	PU-241	0.1782634E-01
16	NB-93M	0.1135641E 00	TE-129M	0.1416066E-01
17	ZR-93	0.1082250E 00	I-129	0.1304285E-01
18	BA-140	0.1026768E 00	SN-125	0.1004329E-01
19	ZN-65	0.8004075E-01	TE-127M	0.9541851E-02
20	ZR-95	0.7083327E-01	CL-36	0.8007091E-02
21	CS-137	0.6969696E-01	S-35	0.7686868E-02
22	CS-134	0.4285714E-01	SR-91	0.6262626E-02
23	SN-125	0.4017317E-01	CO-60	0.4539829E-02
24	Y-90	0.2694180E-01	RB-87	0.4300892E-02
25	PR-143	0.2616642E-01	CS-136	0.4121210E-02
26	RU-106	0.2344879E-01	FE-59	0.3672960E-02
27	IN-115	0.2330448E-01	I-131	0.3551156E-02
28	CE-141	0.2264610E-01	C-14	0.3246754E-02
29	TE-129M	0.2093315E-01	TE-125M	0.2821068E-02
30	SB-125	0.2012988E-01	RU-106	0.2813855E-02
31	ND-147	0.1696970E-01	TL-204	0.2735689E-02
32	CS-135	0.1666666E-01	TE-132	0.2486412E-02
33	NB-95	0.1503847E-01	SR-92	0.2222222E-02
34	TE-127M	0.1410535E-01	SB-125	0.2012988E-02
35	NA-22	0.1401772E-01	NA-24	0.1720357E-02
36	FE-59	0.1101888E-01	HG-203	0.1632747E-02
37	I-129	0.9782135E-02	K-42	0.8835411E-03
38	SR-91	0.8350171E-02	MN-54	0.8773815E-03
39	Y-93	0.6237376E-02	TE-131M	0.8629151E-03
40	CO-60	0.6053109E-02	MO-99	0.8257707E-03
41	CL-36	0.6005317E-02	I-133	0.7760720E-03
42	CD-115M	0.5668148E-02	CE-144	0.5522720E-03
43	LA-140	0.5454544E-02	FE-55	0.5197811E-03
44	S-35	0.5124580E-02	W-185	0.4579125E-03
45	ZR-97	0.4764069E-02	I-135	0.3865489E-03
46	CE-143	0.4558079E-02	TL-201	0.2777774E-03
47	PM-149	0.4523810E-02	AU-196	0.2637878E-03
48	TE-125M	0.4170272E-02	EU-152	0.2214936E-03
49	TE-132	0.3675566E-02	RU-103	0.2147187E-03
50	RB-87	0.3225669E-02	IN-115	0.1980880E-03
51	CS-136	0.3090909E-02	I-132	0.1751153E-03

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = BONE

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
52	NP-239	0.3020371E-02	AU-198	0.1601418E-03
53	SR-92	0.2962963E-02	RH-105	0.1587903E-03
54	TL-204	0.2845116E-02	Y-91	0.1516955E-03
55	I-131	0.2663367E-02	TC-99	0.1412939E-03
56	MN-54	0.2632145E-02	TE-127	0.1294371E-03
57	C-14	0.2597403E-02	H-3	0.1274339E-03
58	Y-92	0.2364719E-02	W-187	0.1060606E-03
59	SM-153	0.2333331E-02	PM-147	0.8396461E-04
60	RU-103	0.1789323E-02	SM-151	0.7889693E-04
61	AG-111	0.1688311E-02	AG-111	0.6493503E-04
62	SC-48	0.1635402E-02	I-134	0.5734524E-04
63	FE-55	0.1559344E-02	CD-115M	0.5668150E-04
64	HG-203	0.1371507E-02	EU-155	0.5321213E-04
65	W-185	0.1308322E-02	PD-109	0.4549386E-04
66	NA-24	0.1290268E-02	ZR-93	0.4329004E-04
67	TE-131M	0.1275613E-02	NB-93M	0.4315439E-04
68	AU-196	0.7913639E-03	TE-129	0.3949496E-04
69	GD-159	0.7440476E-03	CU-64	0.3939829E-04
70	MO-99	0.6709388E-03	W-181	0.3362792E-04
71	K-42	0.6626558E-03	ZR-95	0.2833332E-04
72	I-133	0.5820540E-03	PB-203	0.2661617E-04
73	AU-198	0.4804253E-03	Y-93	0.2462121E-04
74	ND-149	0.4221858E-03	MN-56	0.2219471E-04
75	CD-115	0.4146909E-03	RU-105	0.1919192E-04
76	BE-7	0.3924961E-03	AS-77	0.1223364E-04
77	RH-105	0.3175805E-03	BI-207	0.1142857E-04
78	W-187	0.3030302E-03	Y-90	0.1063492E-04
79	BI-207	0.2933333E-03	PR-143	0.1046657E-04
80	I-135	0.2899116E-03	CE-141	0.9058442E-05
81	TL-201	0.2888886E-03	ND-147	0.6599327E-05
82	Y-91M	0.2398991E-03	NB-95	0.5714621E-05
83	TE-127	0.1913419E-03	CD-115	0.4146909E-05
84	CR-51	0.1765489E-03	CR-51	0.3530977E-05
85	RU-105	0.1599327E-03	PB-204M	0.3504090E-05
86	NB-97	0.1471862E-03	BE-7	0.3139970E-05
87	TC-99	0.1412939E-03	LA-140	0.2181819E-05
88	I-132	0.1313364E-03	ZR-97	0.1905629E-05
89	H-3	0.1274339E-03	CE-143	0.1823232E-05
90	AS-77	0.1101027E-03	PM-149	0.1759259E-05
91	PB-203	0.1064646E-03	NP-239	0.1482727E-05
92	W-181	0.9607978E-04	Y-92	0.9334415E-06
93	PD-109	0.7961424E-04	SM-153	0.9074066E-06
94	IN-115M	0.6762870E-04	RH-103M	0.8682064E-06
95	MN-56	0.6658415E-04	SC-48	0.6541605E-06
96	TE-129	0.5838386E-04	IN-115M	0.5748436E-06
97	CU-64	0.5487620E-04	GD-159	0.3043832E-06
98	I-134	0.4300893E-04	ND-149	0.1641834E-06
99	PB-204M	0.1401636E-04	Y-91M	0.9469699E-07
100	RH-103M	0.1736413E-05	NB-97	0.5593076E-07
101	TC-99M	0.8658009E-08	TC-99M	0.8658009E-08

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. ORGAN = G.I. TRACT

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
1	RU-106	0.7142854E-01	RU-106	0.1948052E 00
2	Y-90	0.5357140E-01	CE-144	0.1948052E 00
3	ZR-97	0.5357140E-01	Y-90	0.9740257E-01
4	SN-125	0.5357140E-01	ZR-97	0.9740257E-01
5	LA-140	0.4285712E-01	SN-125	0.9740257E-01
6	SC-48	0.3571427E-01	LA-140	0.9740257E-01
7	Y-91	0.3571427E-01	SC-48	0.6493503E-01
8	Y-93	0.3571427E-01	Y-91	0.6493503E-01
9	BA-140	0.3571427E-01	Y-93	0.6493503E-01
10	PU-238	0.3571427E-01	TE-129M	0.6493503E-01
11	PU-239	0.3571427E-01	TE-132	0.6493503E-01
12	PU-240	0.3571427E-01	BA-140	0.6493503E-01
13	CD-115M	0.3571427E-01	PU-238	0.6493503E-01
14	TE-129M	0.3061223E-01	PU-239	0.6493503E-01
15	TE-132	0.3061223E-01	PU-240	0.6493503E-01
16	CD-115	0.2678572E-01	CD-115M	0.6493503E-01
17	SR-89	0.2380952E-01	CD-115	0.6493503E-01
18	CE-143	0.2380952E-01	SR-89	0.4870130E-01
19	FE-59	0.2142857E-01	AG-111	0.4870130E-01
20	CO-60	0.2142857E-01	CE-143	0.4870130E-01
21	SR-90	0.2142857E-01	PM-149	0.4870130E-01
22	Y-92	0.2142857E-01	PB-204M	0.4870130E-01
23	ZR-95	0.2142857E-01	CO-60	0.3896103E-01
24	AG-111	0.2142857E-01	SR-90	0.3896103E-01
25	TE-125M	0.2142857E-01	PR-143	0.3896103E-01
26	TE-131M	0.2142857E-01	AU-198	0.3896103E-01
27	PR-143	0.2142857E-01	FE-59	0.3246752E-01
28	ND-147	0.2142857E-01	Y-92	0.3246752E-01
29	PM-149	0.2142857E-01	ZR-95	0.3246752E-01
30	PB-204M	0.2142857E-01	TE-131M	0.3246752E-01
31	AU-198	0.2142857E-01	ND-147	0.3246752E-01
32	BI-207	0.2142857E-01	BI-207	0.3246752E-01
33	P-32	0.1071428E-01	SR-91	0.2782930E-01
34	SR-91	0.1071428E-01	SR-92	0.2782930E-01
35	SR-92	0.1071428E-01	W-187	0.2782930E-01
36	NB-95	0.1071428E-01	RU-103	0.2435064E-01
37	RU-103	0.1071428E-01	TE-127M	0.2435064E-01
38	PD-109	0.1071428E-01	SM-153	0.2435064E-01
39	IN-115	0.1071428E-01	EU-152	0.2435064E-01
40	SB-125	0.1071428E-01	AS-77	0.2435064E-01
41	TE-127M	0.1071428E-01	GD-159	0.2435064E-01
42	CE-141	0.1071428E-01	P-32	0.2164501E-01
43	SM-153	0.1071428E-01	PD-109	0.2164501E-01
44	EU-152	0.1071428E-01	IN-115	0.2164501E-01
45	W-187	0.1071428E-01	CE-141	0.2164501E-01
46	TL-204	0.1071428E-01	MN-54	0.1948051E-01
47	AS-77	0.1071428E-01	MN-56	0.1948051E-01
48	GD-159	0.1071428E-01	NB-95	0.1948051E-01
49	MN-54	0.7142853E-02	RU-105	0.1948051E-01
50	MN-56	0.7142853E-02	SB-125	0.1948051E-01
51	RU-105	0.7142853E-02	W-185	0.1948051E-01

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. ORGAN = G.I. TRACT

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
52	W-185	0.7142853E-02	TL-204	0.1948051E-01
53	NP-239	0.7142853E-02	NP-239	0.1948051E-01
54	RH-105	0.7142853E-02	RH-105	0.1948051E-01
55	NA-24	0.5357139E-02	NA-24	0.9740256E-02
56	ZN-65	0.5357139E-02	ZN-65	0.9740256E-02
57	EU-155	0.5357139E-02	MO-99	0.9740256E-02
58	AU-196	0.5357139E-02	TE-125M	0.9740256E-02
59	PB-210	0.5357139E-02	PM-147	0.9740256E-02
60	MO-99	0.4285712E-02	EU-155	0.9740256E-02
61	PM-147	0.4285712E-02	AU-196	0.9740256E-02
62	TE-127	0.3571427E-02	PB-210	0.9740256E-02
63	ND-149	0.3571427E-02	NA-22	0.6493505E-02
64	NA-22	0.3061223E-02	K-42	0.6493505E-02
65	K-42	0.3061223E-02	CU-64	0.6493505E-02
66	CU-64	0.3061223E-02	TC-99	0.6493505E-02
67	TC-99	0.3061223E-02	TE-127	0.6493505E-02
68	TL-201	0.3061223E-02	ND-149	0.6493505E-02
69	IN-115M	0.2678570E-02	TL-201	0.6493505E-02
70	SM-151	0.2678570E-02	CA-45	0.4870128E-02
71	W-181	0.2678570E-02	NB-93M	0.4870128E-02
72	NB-93M	0.2380951E-02	IN-115M	0.4870128E-02
73	I-132	0.2380951E-02	I-132	0.4870128E-02
74	PB-203	0.2380951E-02	SM-151	0.4870128E-02
75	CA-45	0.2142857E-02	W-181	0.4870128E-02
76	I-133	0.2142857E-02	PB-203	0.4870128E-02
77	I-134	0.2142857E-02	HG-203	0.4870128E-02
78	I-135	0.2142857E-02	I-135	0.3896103E-02
79	CS-134	0.2142857E-02	CS-134	0.3896103E-02
80	HG-203	0.2142857E-02	I-133	0.3246753E-02
81	ZR-93	0.1071428E-02	I-134	0.3246753E-02
82	NB-97	0.1071428E-02	ZR-93	0.2435064E-02
83	TE-129	0.1071428E-02	TE-129	0.2435064E-02
84	I-131	0.1071428E-02	CS-137	0.2435064E-02
85	CS-137	0.1071428E-02	CS-136	0.2435064E-02
86	CS-136	0.1071428E-02	NB-97	0.2164501E-02
87	CL-36	0.7142858E-03	CL-36	0.1948051E-02
88	CE-144	0.7142858E-03	I-131	0.1948051E-02
89	PU-241	0.7142858E-03	PU-241	0.1948051E-02
90	BE-7	0.5357142E-03	BE-7	0.9740260E-03
91	CR-51	0.5357142E-03	CR-51	0.9740260E-03
92	FE-55	0.3571426E-03	FE-55	0.6493505E-03
93	RB-87	0.2678570E-03	RB-87	0.6493505E-03
94	Y-91M	0.2678570E-03	Y-91M	0.6493505E-03
95	I-129	0.2380951E-03	I-129	0.4870128E-03
96	S-35	0.2142856E-03	S-35	0.3896102E-03
97	TC-99M	0.2142856E-03	CS-135	0.3896102E-03
98	CS-135	0.2142856E-03	TC-99M	0.3246751E-03
99	C-14	0.1071428E-03	C-14	0.2164502E-03
100	RH-103M	0.7142856E-04	RH-103M	0.1948052E-03
101	H-3	0.2142855E-04	H-3	0.3896101E-04

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)
GAMMA = 20.5 TAU = 0. ORGAN = G.I. TRACT

INSOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
1	RU-106	0.1071428E 00	RU-106	0.1948052E 00
2	CE-144	0.1071428E 00	CE-144	0.1948052E 00
3	Y-90	0.7142854E-01	P-32	0.9740257E-01
4	ZR-97	0.7142854E-01	K-42	0.9740257E-01
5	SN-125	0.7142854E-01	Y-90	0.9740257E-01
6	P-32	0.5357140E-01	ZR-97	0.9740257E-01
7	K-42	0.5357140E-01	SN-125	0.9740257E-01
8	TE-129M	0.5357140E-01	TE-129M	0.9740257E-01
9	TE-132	0.5357140E-01	TE-132	0.9740257E-01
10	BA-140	0.5357140E-01	BA-140	0.9740257E-01
11	LA-140	0.5357140E-01	LA-140	0.9740257E-01
12	CD-115M	0.5357140E-01	NA-22	0.6493503E-01
13	NA-22	0.4285712E-01	NA-24	0.6493503E-01
14	NA-24	0.4285712E-01	SC-48	0.6493503E-01
15	SC-48	0.4285712E-01	CO-60	0.6493503E-01
16	SR-89	0.4285712E-01	SR-89	0.6493503E-01
17	Y-91	0.4285712E-01	Y-91	0.6493503E-01
18	Y-93	0.4285712E-01	Y-93	0.6493503E-01
19	PU-238	0.4285712E-01	PU-238	0.6493503E-01
20	PU-239	0.4285712E-01	PU-239	0.6493503E-01
21	PU-240	0.4285712E-01	PU-240	0.6493503E-01
22	CO-60	0.3571427E-01	CD-115M	0.6493503E-01
23	SR-90	0.3571427E-01	SR-90	0.4870130E-01
24	TE-131M	0.3571427E-01	MO-99	0.4870130E-01
25	CD-115	0.3571427E-01	AG-111	0.4870130E-01
26	MO-99	0.3061223E-01	TE-131M	0.4870130E-01
27	I-133	0.3061223E-01	I-133	0.4870130E-01
28	CS-134	0.3061223E-01	CS-134	0.4870130E-01
29	CE-143	0.3061223E-01	CS-137	0.4870130E-01
30	AG-111	0.2678572E-01	CE-143	0.4870130E-01
31	CS-137	0.2678572E-01	PM-149	0.4870130E-01
32	PM-149	0.2678572E-01	PB-204M	0.4870130E-01
33	PB-204M	0.2678572E-01	CD-115	0.4870130E-01
34	AU-198	0.2678572E-01	FE-59	0.3896103E-01
35	FE-59	0.2380952E-01	SR-91	0.3896103E-01
36	SR-91	0.2380952E-01	TE-127M	0.3896103E-01
37	TE-127M	0.2380952E-01	PR-143	0.3896103E-01
38	PR-143	0.2380952E-01	AU-198	0.3896103E-01
39	CL-36	0.2142857E-01	CL-36	0.3246752E-01
40	SR-92	0.2142857E-01	SR-92	0.3246752E-01
41	Y-92	0.2142857E-01	Y-92	0.3246752E-01
42	ZR-95	0.2142857E-01	ZR-95	0.3246752E-01
43	RU-103	0.2142857E-01	I-131	0.3246752E-01
44	PD-109	0.2142857E-01	ND-147	0.3246752E-01
45	I-131	0.2142857E-01	W-187	0.3246752E-01
46	I-135	0.2142857E-01	TL-204	0.3246752E-01
47	ND-147	0.2142857E-01	BI-207	0.3246752E-01
48	SM-153	0.2142857E-01	CS-136	0.3246752E-01
49	EU-152	0.2142857E-01	PD-109	0.2782930E-01
50	W-187	0.2142857E-01	I-135	0.2782930E-01
51	TL-204	0.2142857E-01	RU-103	0.2435064E-01

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. ORGAN = G.I. TRACT

INSOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
52	BI-207	0.2142857E-01	SM-153	0.2435064E-01
53	CS-136	0.2142857E-01	EU-152	0.2435064E-01
54	AS-77	0.2142857E-01	AS-77	0.2435064E-01
55	GD-159	0.2142857E-01	GD-159	0.2435064E-01
56	MN-54	0.1071428E-01	IN-115	0.2164501E-01
57	MN-56	0.1071428E-01	CE-141	0.2164501E-01
58	NB-95	0.1071428E-01	MN-54	0.1948051E-01
59	RU-105	0.1071428E-01	MN-56	0.1948051E-01
60	IN-115	0.1071428E-01	NB-95	0.1948051E-01
61	SB-125	0.1071428E-01	RU-105	0.1948051E-01
62	TE-125M	0.1071428E-01	SB-125	0.1948051E-01
63	CE-141	0.1071428E-01	TE-125M	0.1948051E-01
64	W-185	0.1071428E-01	W-185	0.1948051E-01
65	HG-203	0.1071428E-01	AU-196	0.1948051E-01
66	NP-239	0.1071428E-01	HG-203	0.1948051E-01
67	RH-105	0.1071428E-01	NP-239	0.1948051E-01
68	CA-45	0.7142853E-02	RH-105	0.1948051E-01
69	ZN-65	0.7142853E-02	C-14	0.9740256E-02
70	RB-87	0.7142853E-02	CA-45	0.9740256E-02
71	TC-99	0.7142853E-02	CU-64	0.9740256E-02
72	TE-127	0.7142853E-02	ZN-65	0.9740256E-02
73	I-132	0.7142853E-02	RB-87	0.9740256E-02
74	AU-196	0.7142853E-02	TC-99	0.9740256E-02
75	TL-201	0.7142853E-02	TE-127	0.9740256E-02
76	PB-210	0.7142853E-02	I-129	0.9740256E-02
77	C-14	0.5357139E-02	I-132	0.9740256E-02
78	CU-64	0.5357139E-02	CS-135	0.9740256E-02
79	I-129	0.5357139E-02	PM-147	0.9740256E-02
80	CS-135	0.5357139E-02	EU-155	0.9740256E-02
81	PM-147	0.5357139E-02	TL-201	0.9740256E-02
82	EU-155	0.5357139E-02	PB-210	0.9740256E-02
83	S-35	0.4285712E-02	S-35	0.6493505E-02
84	ND-149	0.4285712E-02	ND-149	0.6493505E-02
85	IN-115M	0.3571427E-02	W-181	0.6493505E-02
86	W-181	0.3571427E-02	NB-93M	0.4870128E-02
87	PB-203	0.3571427E-02	IN-115M	0.4870128E-02
88	NB-93M	0.3061223E-02	SM-151	0.4870128E-02
89	SM-151	0.3061223E-02	PB-203	0.4870128E-02
90	ZR-93	0.2142857E-02	I-134	0.3246753E-02
91	TE-129	0.2142857E-02	ZR-93	0.2435064E-02
92	I-134	0.2142857E-02	TE-129	0.2435064E-02
93	H-3	0.1071428E-02	NB-97	0.2164501E-02
94	NB-97	0.1071428E-02	H-3	0.1948051E-02
95	PU-241	0.1071428E-02	PU-241	0.1948051E-02
96	BE-7	0.7142858E-03	BE-7	0.9740260E-03
97	CR-51	0.7142858E-03	FE-55	0.9740260E-03
98	FE-55	0.5357142E-03	CR-51	0.9740260E-03
99	TC-99M	0.4285711E-03	Y-91M	0.6493505E-03
100	Y-91M	0.3571426E-03	TC-99M	0.6493505E-03
101	RH-103M	0.1071428E-03	RH-103M	0.1948052E-03

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = KIDNEYS

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
1	PU-239	0.8554993E 03	PB-210	0.1172741E 02
2	PU-240	0.8554993E 03	SR-90	0.1908106E 01
3	PU-238	0.7245693E 03	PU-239	0.1026599E 00
4	PB-210	0.4690964E 02	PU-240	0.1026599E 00
5	PU-241	0.1227937E 02	HG-203	0.1018432E 00
6	SR-90	0.2544142E 01	PU-238	0.8694834E-01
7	EU-152	0.5007589E 00	TE-129M	0.5925426E-01
8	CE-144	0.2947280E 00	CS-134	0.4368102E-01
9	CD-115M	0.1375715E 00	CS-137	0.3689147E-01
10	TE-129M	0.8888137E-01	TE-127M	0.3494480E-01
11	HG-203	0.8617502E-01	NA-22	0.1869029E-01
12	EU-155	0.6472737E-01	TE-125M	0.1329423E-01
13	TE-127M	0.5241720E-01	TE-132	0.1321826E-01
14	RU-106	0.3826836E-01	I-129	0.1304285E-01
15	BI-207	0.3760365E-01	MO-99	0.9828232E-02
16	CS-134	0.3276075E-01	ZN-65	0.9714264E-02
17	ZR-95	0.3221475E-01	TL-204	0.9555228E-02
18	SM-151	0.3215540E-01	CA-45	0.8877035E-02
19	PM-147	0.3136842E-01	SR-89	0.8813635E-02
20	ZN-65	0.2914282E-01	CL-36	0.8007091E-02
21	NB-93M	0.2880746E-01	P-32	0.7419035E-02
22	CS-137	0.2766860E-01	CS-136	0.6884508E-02
23	IN-115	0.2421447E-01	CS-135	0.6580640E-02
24	ZR-93	0.2350229E-01	TE-131M	0.4614990E-02
25	TE-125M	0.1994134E-01	RU-106	0.4592199E-02
26	TE-132	0.1982739E-01	RB-87	0.4300892E-02
27	NA-22	0.1401772E-01	FE-59	0.3672960E-02
28	SR-89	0.1175152E-01	I-131	0.3551156E-02
29	FE-59	0.1101888E-01	S-35	0.2634482E-02
30	TL-204	0.9970672E-02	TC-99	0.2231531E-02
31	I-129	0.9782135E-02	NA-24	0.1720357E-02
32	Y-91	0.9084973E-02	PU-241	0.1473524E-02
33	MO-99	0.8190192E-02	BI-207	0.1410137E-02
34	ND-147	0.8168824E-02	CD-115M	0.1375714E-02
35	CA-45	0.8137282E-02	TL-201	0.1261289E-02
36	NB-95	0.7952791E-02	PD-109	0.1116714E-02
37	CD-115	0.7311821E-02	K-42	0.8835411E-03
38	TE-131M	0.6922487E-02	MN-54	0.8773815E-03
39	CE-141	0.6409705E-02	AU-198	0.7883946E-03
40	RU-103	0.6267276E-02	I-133	0.7760720E-03
41	P-32	0.6231990E-02	CO-60	0.7577704E-03
42	CL-36	0.6005317E-02	RU-103	0.7520728E-03
43	CS-136	0.5163379E-02	AU-196	0.5875572E-03
44	PR-143	0.5127765E-02	C-14	0.5734523E-03
45	CS-135	0.4935477E-02	TE-127	0.4444069E-03
46	SB-125	0.3715969E-02	SB-125	0.4128853E-03
47	RB-87	0.3225669E-02	RH-105	0.3897103E-03
48	I-131	0.2663367E-02	I-135	0.3865489E-03
49	MN-54	0.2632145E-02	SN-125	0.3743365E-03
50	AU-198	0.2365184E-02	PB-203	0.3538160E-03
51	TC-99	0.2231531E-02	FE-55	0.3195934E-03

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = KIDNEYS

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
52	SN-125	0.2096285E-02	SR-91	0.2676109E-03
53	S-35	0.1975861E-02	RU-105	0.2153664E-03
54	SC-48	0.1816085E-02	CU-64	0.2058231E-03
55	RU-105	0.1794720E-02	EU-152	0.2003036E-03
56	AU-196	0.1762672E-02	IN-115	0.1937158E-03
57	AG-111	0.1756737E-02	I-132	0.1751153E-03
58	PD-109	0.1675072E-02	TE-129	0.1646584E-03
59	PB-203	0.1415265E-02	H-3	0.1274339E-03
60	TL-201	0.1316128E-02	CE-144	0.1178912E-03
61	CE-143	0.1294525E-02	SR-92	0.9111511E-04
62	NA-24	0.1290268E-02	CD-115	0.7311816E-04
63	ZR-97	0.1264138E-02	AG-111	0.7026950E-04
64	PM-149	0.1096772E-02	I-134	0.5734524E-04
65	CO-60	0.1010360E-02	PB-204M	0.4909361E-04
66	FE-55	0.9587801E-03	W-187	0.3610624E-04
67	NP-239	0.8711864E-03	AS-77	0.2734810E-04
68	LA-140	0.8474349E-03	EU-155	0.2589096E-04
69	BE-7	0.7905306E-03	MN-56	0.2219471E-04
70	TE-127	0.6666104E-03	W-181	0.2123897E-04
71	K-42	0.6626558E-03	W-185	0.1486728E-04
72	RH-105	0.6495176E-03	ZR-95	0.1288590E-04
73	Y-90	0.6332397E-03	SM-151	0.1286216E-04
74	I-133	0.5820540E-03	PM-147	0.1254737E-04
75	SM-153	0.5786545E-03	NB-93M	0.1154699E-04
76	C-14	0.4300892E-03	ZR-93	0.9400916E-05
77	CU-64	0.4116462E-03	BA-140	0.7264337E-05
78	SR-91	0.3568146E-03	BE-7	0.6324247E-05
79	I-135	0.2899116E-03	ND-147	0.4084414E-05
80	TE-129	0.2469874E-03	Y-91	0.3633989E-05
81	AS-77	0.2461327E-03	NB-95	0.3181117E-05
82	PB-204M	0.1963745E-03	RH-103M	0.2922828E-05
83	ND-149	0.1911281E-03	CE-141	0.2563882E-05
84	Y-93	0.1895578E-03	PR-143	0.2051107E-05
85	I-132	0.1313364E-03	TC-99M	0.1111017E-05
86	H-3	0.1274339E-03	CR-51	0.9851010E-06
87	SR-92	0.1214868E-03	SC-48	0.7264341E-06
88	W-187	0.1083188E-03	IN-115M	0.6856024E-06
89	IN-115M	0.8570027E-04	CE-143	0.5178100E-06
90	GD-159	0.7168151E-04	ZR-97	0.5056555E-06
91	MN-56	0.6658415E-04	PM-149	0.4387090E-06
92	W-181	0.6371693E-04	NP-239	0.3484746E-06
93	Y-92	0.6371690E-04	LA-140	0.3389739E-06
94	CR-51	0.5152838E-04	Y-90	0.2532959E-06
95	W-185	0.4460184E-04	SM-153	0.2314619E-06
96	I-134	0.4300893E-04	ND-149	0.9556402E-07
97	BA-140	0.4068027E-04	Y-93	0.7582310E-07
98	NB-97	0.3632170E-04	GD-159	0.2867260E-07
99	Y-91M	0.8641608E-05	Y-92	0.2548676E-07
100	RH-103M	0.4871381E-05	NB-97	0.1452868E-07
101	TC-99M	0.1111017E-05	Y-91M	0.3456643E-08

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = LIVER

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
1	PU-239	0.1208649E 04	PB-210	0.4307852E 01
2	PU-240	0.1208649E 04	SR-90	0.1908106E 01
3	PU-238	0.1040906E 04	CS-134	0.1450276E 00
4	PB-210	0.1548135E 02	PU-239	0.1431295E 00
5	PU-241	0.6898226E 01	PU-240	0.1431295E 00
6	SR-90	0.2544142E 01	PU-238	0.1232652E 00
7	CE-144	0.5110227E 00	CS-137	0.1146211E 00
8	CD-115M	0.1820306E 00	NA-22	0.1869029E-01
9	EU-152	0.1101741E 00	CS-135	0.1865852E-01
10	CS-134	0.1035911E 00	ZN-65	0.1554878E-01
11	CS-137	0.8187217E-01	I-129	0.1304285E-01
12	ZN-65	0.4886757E-01	RB-87	0.1272171E-01
13	SM-151	0.3154985E-01	CS-136	0.1253325E-01
14	FE-59	0.3143678E-01	P-32	0.1238516E-01
15	ZR-95	0.2711275E-01	FE-59	0.1021695E-01
16	EU-155	0.2685696E-01	CA-45	0.8877035E-02
17	PM-147	0.2371759E-01	SR-89	0.8813635E-02
18	NB-93M	0.2346361E-01	HG-203	0.8727051E-02
19	ND-147	0.1866750E-01	CL-36	0.8007091E-02
20	IN-115	0.1769822E-01	TE-129M	0.5959239E-02
21	MN-54	0.1661676E-01	MN-54	0.4747644E-02
22	CE-141	0.1405447E-01	MO-99	0.4488096E-02
23	NA-22	0.1401772E-01	I-131	0.3551156E-02
24	CS-135	0.1332751E-01	TE-127M	0.3302710E-02
25	BI-207	0.1203515E-01	S-35	0.2634482E-02
26	TE-129M	0.1191849E-01	CO-60	0.2148558E-02
27	SR-89	0.1175152E-01	CD-115M	0.1820306E-02
28	CD-115	0.1087920E-01	NA-24	0.1720357E-02
29	RB-87	0.1017737E-01	TE-132	0.1431473E-02
30	P-32	0.9908132E-02	FE-55	0.1395395E-02
31	I-129	0.9782135E-02	TE-125M	0.1256466E-02
32	PR-143	0.9477343E-02	TL-204	0.1121846E-02
33	Y-91	0.9084973E-02	PU-241	0.8168952E-03
34	CS-136	0.8952320E-02	I-133	0.7760720E-03
35	CA-45	0.8137282E-02	K-42	0.7000314E-03
36	NB-95	0.7840347E-02	C-14	0.5734523E-03
37	HG-203	0.7140316E-02	TE-131M	0.5223309E-03
38	TE-127M	0.6605420E-02	BI-207	0.4513182E-03
39	ZR-93	0.6318230E-02	SB-125	0.4128853E-03
40	CO-60	0.6138735E-02	I-135	0.3865489E-03
41	CL-36	0.6005317E-02	RU-106	0.3211331E-03
42	FE-55	0.4293524E-02	SR-91	0.2676109E-03
43	SB-125	0.3715969E-02	AU-198	0.2132401E-03
44	MO-99	0.3646579E-02	CE-144	0.2129261E-03
45	SC-48	0.3356559E-02	AU-196	0.2073169E-03
46	LA-140	0.3317070E-02	PD-109	0.2073169E-03
47	CE-143	0.3020904E-02	TL-201	0.2046245E-03
48	RU-106	0.2890198E-02	TC-99	0.1898162E-03
49	TE-132	0.2862947E-02	SN-125	0.1771617E-03
50	I-131	0.2663367E-02	I-132	0.1751153E-03
51	TE-125M	0.2512933E-02	W-185	0.1432371E-03

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = LIVER

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
52	SM-153	0.2037090E-02	MN-56	0.1283390E-03
53	S-35	0.1975861E-02	H-3	0.1274339E-03
54	NA-24	0.1290268E-02	IN-115	0.1238875E-03
55	TL-204	0.1121846E-02	CD-115	0.1087920E-03
56	TE-131M	0.1044662E-02	RH-105	0.9549143E-04
57	ZR-97	0.1019533E-02	W-187	0.9477336E-04
58	SN-125	0.9921058E-03	W-181	0.9135396E-04
59	PM-149	0.8687566E-03	SR-92	0.9111511E-04
60	BE-7	0.8077284E-03	CU-64	0.9037583E-04
61	RU-103	0.7821887E-03	RU-103	0.8690984E-04
62	AG-111	0.6565035E-03	PB-203	0.5858143E-04
63	Y-90	0.6332397E-03	I-134	0.5734524E-04
64	I-133	0.5820540E-03	EU-152	0.4590585E-04
65	AU-198	0.5331005E-03	TE-127	0.4200185E-04
66	K-42	0.5250233E-03	AG-111	0.2557805E-04
67	AU-196	0.5182924E-03	BA-140	0.2374721E-04
68	ND-149	0.4793461E-03	TE-129	0.1670652E-04
69	W-185	0.4774572E-03	AS-77	0.1550837E-04
70	MN-56	0.4491864E-03	SM-151	0.1226939E-04
71	C-14	0.4300892E-03	EU-155	0.1119040E-04
72	SR-91	0.3568146E-03	NB-93M	0.1055862E-04
73	GD-159	0.3331879E-03	ZR-95	0.9489462E-05
74	W-187	0.3159114E-03	PB-204M	0.7963840E-05
75	PD-109	0.3109751E-03	RU-105	0.7263729E-05
76	W-181	0.3045131E-03	ND-147	0.7179807E-05
77	NP-239	0.2990300E-03	PM-147	0.7115277E-05
78	I-135	0.2899116E-03	BE-7	0.6461828E-05
79	PB-203	0.2105271E-03	CE-141	0.5856024E-05
80	TL-201	0.2046245E-03	PR-143	0.3790937E-05
81	TC-99	0.1898162E-03	Y-91	0.3633989E-05
82	Y-93	0.1895578E-03	CR-51	0.3530977E-05
83	CR-51	0.1765489E-03	NB-95	0.3528156E-05
84	RH-105	0.1671100E-03	ZR-93	0.2211381E-05
85	AS-77	0.1378522E-03	SC-48	0.1258709E-05
86	CU-64	0.1355637E-03	CE-143	0.1258709E-05
87	BA-140	0.1345676E-03	LA-140	0.1243900E-05
88	I-132	0.1313364E-03	SM-153	0.7922017E-06
89	H-3	0.1274339E-03	RH-103M	0.7502896E-06
90	SR-92	0.1214868E-03	IN-115M	0.4774571E-06
91	TE-127	0.8400372E-04	ZR-97	0.3568364E-06
92	IN-115M	0.6820820E-04	PM-149	0.2606270E-06
93	RU-105	0.6537356E-04	Y-90	0.2532959E-06
94	Y-92	0.6371690E-04	ND-149	0.1843639E-06
95	I-134	0.4300893E-04	GD-159	0.1332751E-06
96	TE-129	0.3341303E-04	NP-239	0.1150116E-06
97	NB-97	0.2929360E-04	TC-99M	0.8481140E-07
98	PB-204M	0.2862005E-04	Y-93	0.7582310E-07
99	Y-91M	0.8641608E-05	Y-92	0.2548676E-07
100	RH-103M	0.1313007E-05	NB-97	0.1318212E-07
101	TC-99M	0.8481140E-07	Y-91M	0.3456643E-08

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = LUNGS

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
1	PU-239	0.2176467E 03	SR-90	0.1908106E 01
2	PU-240	0.2171915E 03	PB-210	0.5301245E 00
3	PU-238	0.1840500E 03	PU-239	0.2611759E-01
4	PU-241	0.2694068E 01	PU-240	0.2606297E-01
5	SR-90	0.2544142E 01	PU-238	0.2208599E-01
6	PB-210	0.1921701E 01	NA-22	0.1869029E-01
7	EU-152	0.9794879E-01	CS-134	0.1502616E-01
8	CE-144	0.6592041E-01	I-129	0.1304285E-01
9	ZN-65	0.1977771E-01	CS-137	0.1242953E-01
10	ZR-95	0.1620798E-01	CA-45	0.8877035E-02
11	NA-22	0.1401772E-01	SR-89	0.8813635E-02
12	EU-155	0.1333808E-01	CL-36	0.8007091E-02
13	SB-125	0.1212637E-01	P-32	0.7419035E-02
14	SR-89	0.1175152E-01	ZN-65	0.6592568E-02
15	CS-134	0.1152006E-01	CO-60	0.4539829E-02
16	I-129	0.9782135E-02	RB-87	0.4300892E-02
17	CS-137	0.9529307E-02	I-131	0.3551156E-02
18	Y-91	0.9084973E-02	TE-129M	0.2920358E-02
19	FE-59	0.8211657E-02	FE-59	0.2737220E-02
20	CA-45	0.8137282E-02	S-35	0.2634482E-02
21	SM-151	0.7192045E-02	CS-135	0.2029850E-02
22	PM-147	0.7016025E-02	NA-24	0.1720357E-02
23	NB-93M	0.6355762E-02	HG-203	0.1632747E-02
24	P-32	0.6231990E-02	SB-125	0.1364217E-02
25	CO-60	0.6053109E-02	TE-132	0.1311506E-02
26	CL-36	0.6005317E-02	TE-127M	0.1104427E-02
27	CD-115M	0.5668148E-02	CS-136	0.9149699E-03
28	NB-95	0.4535846E-02	K-42	0.8835411E-03
29	TE-129M	0.4438940E-02	MN-54	0.8773815E-03
30	RB-87	0.3225669E-02	MO-99	0.8257707E-03
31	RU-106	0.2890198E-02	FE-55	0.7796467E-03
32	I-131	0.2663367E-02	I-133	0.7760720E-03
33	MN-54	0.2632145E-02	C-14	0.5734523E-03
34	ZR-93	0.2628322E-02	TE-131M	0.4884962E-03
35	FE-55	0.2338939E-02	TE-125M	0.4778770E-03
36	IN-115	0.2166375E-02	I-135	0.3865489E-03
37	SN-125	0.2096285E-02	SN-125	0.3743365E-03
38	TE-132	0.1993489E-02	PU-241	0.3232881E-03
39	S-35	0.1975861E-02	RU-106	0.3211331E-03
40	TE-127M	0.1678728E-02	TL-204	0.2965690E-03
41	CE-141	0.1672569E-02	SR-91	0.2676109E-03
42	CS-135	0.1556218E-02	AU-196	0.2637878E-03
43	BI-207	0.1380534E-02	I-132	0.1751153E-03
44	HG-203	0.1371507E-02	AU-198	0.1601418E-03
45	NA-24	0.1290268E-02	H-3	0.1274339E-03
46	ND-147	0.1178763E-02	SR-92	0.9111511E-04
47	PR-143	0.1146904E-02	RU-103	0.8690984E-04
48	SC-48	0.9929221E-03	I-134	0.5734524E-04
49	LA-140	0.8474349E-03	CD-115M	0.5668150E-04
50	AU-196	0.7913639E-03	RH-105	0.5649564E-04
51	RU-103	0.7821887E-03	BI-207	0.5309744E-04

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = LUNGS

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
52	TE-131M	0.7425142E-03	TL-201	0.4745103E-04
53	TE-125M	0.7263729E-03	PD-109	0.4549386E-04
54	CS-136	0.7014771E-03	PB-203	0.4055790E-04
55	MO-99	0.6709388E-03	CU-64	0.3939829E-04
56	K-42	0.6626558E-03	EU-152	0.3917952E-04
57	Y-90	0.6332397E-03	W-187	0.3610624E-04
58	I-133	0.5820540E-03	CE-144	0.2636816E-04
59	AU-198	0.4804253E-03	TE-127	0.2421242E-04
60	C-14	0.4300892E-03	MN-56	0.2219471E-04
61	CD-115	0.4146909E-03	W-181	0.2123897E-04
62	ZR-97	0.3958412E-03	IN-115	0.1733098E-04
63	BE-7	0.3809740E-03	TC-99	0.1548749E-04
64	SR-91	0.3568146E-03	W-185	0.1486728E-04
65	CE-143	0.3425048E-03	TE-129	0.1326905E-04
66	AG-111	0.3313280E-03	BA-140	0.1312225E-04
67	TL-204	0.3185370E-03	AG-111	0.1274338E-04
68	PM-149	0.3153987E-03	AS-77	0.1223364E-04
69	I-135	0.2899116E-03	RU-105	0.7263729E-05
70	CR-51	0.2726968E-03	ZR-95	0.6483190E-05
71	Y-93	0.1895578E-03	CR-51	0.5453939E-05
72	NP-239	0.1793897E-03	PB-204M	0.5350517E-05
73	SM-153	0.1553100E-03	EU-155	0.5335231E-05
74	PB-203	0.1470225E-03	CD-115	0.4146909E-05
75	I-132	0.1313364E-03	Y-91	0.3633989E-05
76	H-3	0.1274339E-03	BE-7	0.3047791E-05
77	SR-92	0.1214868E-03	SM-151	0.2876818E-05
78	AS-77	0.1101027E-03	PM-147	0.2806410E-05
79	W-187	0.1083188E-03	NB-93M	0.2542305E-05
80	RH-105	0.9886739E-04	NB-95	0.1814338E-05
81	PD-109	0.7961424E-04	ZR-93	0.1051329E-05
82	BA-140	0.7217238E-04	CE-141	0.6690274E-06
83	GD-159	0.7168151E-04	ND-147	0.4715051E-06
84	MN-56	0.6658415E-04	PR-143	0.4587616E-06
85	RU-105	0.6537356E-04	RH-103M	0.4438943E-06
86	W-181	0.6371693E-04	SC-48	0.3971688E-06
87	Y-92	0.6371690E-04	LA-140	0.3389739E-06
88	CU-64	0.5487620E-04	Y-90	0.2532959E-06
89	TL-201	0.5096593E-04	ZR-97	0.1583365E-06
90	W-185	0.4460184E-04	CE-143	0.1370020E-06
91	I-134	0.4300893E-04	PM-149	0.1261595E-06
92	TE-127	0.3680289E-04	IN-115M	0.1049205E-06
93	ND-149	0.2423895E-04	Y-93	0.7582310E-07
94	TE-129	0.2016894E-04	NP-239	0.7175584E-07
95	PB-204M	0.1939562E-04	SM-153	0.6212400E-07
96	TC-99	0.1548749E-04	TC-99M	0.4151964E-07
97	IN-115M	0.1311507E-04	GD-159	0.2867260E-07
98	NB-97	0.1177966E-04	Y-92	0.2548676E-07
99	Y-91M	0.8641608E-05	ND-149	0.9695579E-08
100	RH-103M	0.7768150E-06	NB-97	0.4711861E-08
101	TC-99M	0.4151964E-07	Y-91M	0.3456643E-08

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = LUNG

INSOLUBLE

INHALATION

NO.	NUCLIDE	REM/MICROCI
1	PU-238	0.1883523E 03
2	PU-239	0.1770646E 03
3	PU-240	0.1770449E 03
4	PB-210	0.2700369E 02
5	SR-90	0.1193916E 01
6	RU-106	0.1157287E 01
7	CE-144	0.1009995E 01
8	NA-22	0.7801747E 00
9	CO-60	0.7438690E 00
10	CS-134	0.5478287E 00
11	BI-207	0.4746414E 00
12	CS-137	0.4454854E 00
13	EU-152	0.3534488E 00
14	CL-36	0.2855847E 00
15	TL-204	0.2475911E 00
16	SB-125	0.2415165E 00
17	ZR-93	0.2196808E 00
18	Y-91	0.2111651E 00
19	ZR-95	0.1972451E 00
20	TE-129M	0.1966357E 00
21	IN-115	0.1867286E 00
22	MN-54	0.1804520E 00
23	SR-89	0.1789334E 00
24	CD-115M	0.1767553E 00
25	PU-241	0.1645585E 00
26	TE-127M	0.1640282E 00
27	BA-140	0.1482183E 00
28	FE-59	0.1260202E 00
29	ZN-65	0.1105927E 00
30	TC-99	0.1032497E 00
31	RB-87	0.9885627E-01
32	I-129	0.9006906E-01
33	EU-155	0.8744979E-01
34	P-32	0.8069950E-01
35	SN-125	0.7735479E-01
36	RU-103	0.7552379E-01
37	CS-135	0.7249463E-01
38	PM-147	0.6704479E-01
39	NB-95	0.6448686E-01
40	C-14	0.5931024E-01
41	W-185	0.5865700E-01
42	CA-45	0.5454886E-01
43	HG-203	0.5158121E-01
44	W-181	0.5145593E-01
45	TE-125M	0.5010696E-01
46	SM-151	0.4598379E-01
47	CE-141	0.4162372E-01
48	NB-93M	0.4042817E-01
49	CS-136	0.3757697E-01
50	PR-143	0.3601646E-01
51	TE-132	0.3138292E-01

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = LUNG

NO.	NUCLIDE	INSOLUBLE INHALATION REM/MICROCI
52	ND-147	0.2835938E-01
53	S-35	0.2586950E-01
54	AG-111	0.2455255E-01
55	Y-90	0.2135565E-01
56	I-131	0.2071571E-01
57	SC-48	0.1814894E-01
58	LA-140	0.1668186E-01
59	MO-99	0.1197965E-01
60	CD-115	0.1146941E-01
61	TE-131M	0.1132375E-01
62	H-3	0.1069874E-01
63	AU-198	0.1063490E-01
64	ZR-97	0.1033706E-01
65	AU-196	0.1028442E-01
66	CE-143	0.9993631E-02
67	PM-149	0.8700930E-02
68	NA-24	0.8604761E-02
69	K-42	0.7108819E-02
70	FE-55	0.6437365E-02
71	Y-93	0.5746506E-02
72	SR-91	0.5473774E-02
73	BE-7	0.5426209E-02
74	I-133	0.5059905E-02
75	SM-153	0.4589587E-02
76	W-187	0.3994193E-02
77	AS-77	0.3511424E-02
78	NP-239	0.3347378E-02
79	TL-201	0.3214837E-02
80	CR-51	0.2892412E-02
81	RH-105	0.2610427E-02
82	GD-159	0.2251385E-02
83	PD-109	0.2180956E-02
84	Y-92	0.2056933E-02
85	SR-92	0.2011896E-02
86	I-135	0.1968871E-02
87	PB-203	0.1833936E-02
88	RU-105	0.1580113E-02
89	MN-56	0.1307731E-02
90	CU-64	0.9176908E-03
91	I-132	0.8871586E-03
92	TE-127	0.8539795E-03
93	ND-149	0.7516113E-03
94	I-134	0.3623643E-03
95	IN-115M	0.3472778E-03
96	TE-129	0.3406350E-03
97	NB-97	0.2986388E-03
98	PB-204M	0.2537232E-03
99	Y-91M	0.1761509E-03
100	RH-103M	0.1912448E-04
101	TC-99M	0.1152978E-04

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)
GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = MUSCLE
SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
1	PU-239	0.2176467E 03	SR-90	0.1908106E 01
2	PU-240	0.2171915E 03	PB-210	0.5301245E 00
3	PU-238	0.1840500E 03	CS-134	0.1689439E 00
4	PU-241	0.2694068E 01	CS-137	0.1042077E 00
5	SR-90	0.2544142E 01	PU-239	0.2611759E-01
6	PB-210	0.1921701E 01	PU-240	0.2606297E-01
7	CS-134	0.1267079E 00	PU-238	0.2208599E-01
8	EU-152	0.9794879E-01	NA-22	0.1869029E-01
9	CS-137	0.7815576E-01	I-129	0.1304285E-01
10	CE-144	0.6592041E-01	CS-135	0.1182608E-01
11	ZN-65	0.2008897E-01	RB-87	0.1036702E-01
12	ZR-95	0.1620798E-01	CS-136	0.9899866E-02
13	NA-22	0.1401772E-01	CA-45	0.8877035E-02
14	EU-155	0.1333808E-01	SR-89	0.8813635E-02
15	SR-89	0.1175152E-01	CL-36	0.8007091E-02
16	FE-59	0.1101888E-01	P-32	0.7419035E-02
17	I-129	0.9782135E-02	ZN-65	0.6696325E-02
18	Y-91	0.9084973E-02	CO-60	0.4539829E-02
19	CS-135	0.8869559E-02	FE-59	0.3672960E-02
20	CA-45	0.8137282E-02	I-131	0.3551156E-02
21	RB-87	0.7832855E-02	TE-129M	0.2920358E-02
22	CS-136	0.7424898E-02	S-35	0.2634482E-02
23	SM-151	0.7192045E-02	K-42	0.1730396E-02
24	PM-147	0.7016025E-02	NA-24	0.1720357E-02
25	NB-93M	0.6355762E-02	HG-203	0.1632747E-02
26	P-32	0.6231990E-02	TE-132	0.1311506E-02
27	CO-60	0.6053109E-02	TE-127M	0.1104427E-02
28	CL-36	0.6005317E-02	TL-204	0.1055900E-02
29	CD-115M	0.5668148E-02	MN-54	0.8773815E-03
30	NB-95	0.4535846E-02	MO-99	0.8257707E-03
31	TE-129M	0.4438940E-02	I-133	0.7760720E-03
32	SB-125	0.3715969E-02	C-14	0.5734523E-03
33	RU-106	0.2890198E-02	TE-131M	0.4884962E-03
34	I-131	0.2663367E-02	TE-125M	0.4778770E-03
35	MN-54	0.2632145E-02	SB-125	0.4128853E-03
36	ZR-93	0.2628322E-02	I-135	0.3865489E-03
37	IN-115	0.2166375E-02	SN-125	0.3743365E-03
38	SN-125	0.2096285E-02	PU-241	0.3232881E-03
39	TE-132	0.1993489E-02	RU-106	0.3211331E-03
40	S-35	0.1975861E-02	FE-55	0.3195934E-03
41	TE-127M	0.1678728E-02	SR-91	0.2676109E-03
42	CE-141	0.1672569E-02	AU-196	0.2637878E-03
43	BI-207	0.1380534E-02	TL-201	0.2480401E-03
44	HG-203	0.1371507E-02	I-132	0.1751153E-03
45	K-42	0.1304453E-02	AU-198	0.1601418E-03
46	NA-24	0.1290268E-02	H-3	0.1274339E-03
47	ND-147	0.1178763E-02	SR-92	0.9111511E-04
48	PR-143	0.1146904E-02	RU-103	0.8690984E-04
49	TL-204	0.1143892E-02	I-134	0.5734524E-04
50	SC-48	0.9929221E-03	CD-115M	0.5668150E-04
51	FE-55	0.9587801E-03	RH-105	0.5649564E-04

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = MUSCLE

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
52	LA-140	0.8474349E-03	BI-207	0.5309744E-04
53	AU-196	0.7913639E-03	TC-99	0.4991160E-04
54	RU-103	0.7821887E-03	PD-109	0.4549386E-04
55	TE-131M	0.7425142E-03	PB-203	0.4055790E-04
56	TE-125M	0.7263729E-03	CU-64	0.3939829E-04
57	MO-99	0.6709388E-03	EU-152	0.3917952E-04
58	Y-90	0.6332397E-03	W-187	0.3610624E-04
59	I-133	0.5820540E-03	CE-144	0.2636816E-04
60	AU-198	0.4804253E-03	TE-127	0.2421242E-04
61	C-14	0.4300892E-03	MN-56	0.2219471E-04
62	CD-115	0.4146909E-03	W-181	0.2123897E-04
63	ZR-97	0.3958412E-03	IN-115	0.1733098E-04
64	BE-7	0.3809740E-03	W-185	0.1486728E-04
65	SR-91	0.3568146E-03	BA-140	0.1401947E-04
66	CE-143	0.3425048E-03	TE-129	0.1326905E-04
67	AG-111	0.3313280E-03	AG-111	0.1274338E-04
68	PM-149	0.3153987E-03	AS-77	0.1223364E-04
69	I-135	0.2899116E-03	RU-105	0.7263729E-05
70	TL-201	0.2687103E-03	ZR-95	0.6483190E-05
71	Y-93	0.1895578E-03	PB-204M	0.5350517E-05
72	NP-239	0.1793897E-03	EU-155	0.5335231E-05
73	CR-51	0.1765489E-03	CD-115	0.4146909E-05
74	SM-153	0.1553100E-03	Y-91	0.3633989E-05
75	PB-203	0.1470225E-03	CR-51	0.3530977E-05
76	I-132	0.1313364E-03	BE-7	0.3047791E-05
77	H-3	0.1274339E-03	SM-151	0.2876818E-05
78	SR-92	0.1214868E-03	PM-147	0.2806410E-05
79	AS-77	0.1101027E-03	NB-93M	0.2542305E-05
80	W-187	0.1083188E-03	NB-95	0.1814338E-05
81	RH-105	0.9886739E-04	TC-99M	0.1529205E-05
82	PD-109	0.7961424E-04	ZR-93	0.1051329E-05
83	BA-140	0.7757437E-04	CE-141	0.6690274E-06
84	GD-159	0.7168151E-04	ND-147	0.4715051E-06
85	MN-56	0.6658415E-04	PR-143	0.4587616E-06
86	RU-105	0.6537356E-04	RH-103M	0.4438943E-06
87	W-181	0.6371693E-04	SC-48	0.3971688E-06
88	Y-92	0.6371690E-04	LA-140	0.3389739E-06
89	CU-64	0.5487620E-04	Y-90	0.2532959E-06
90	TC-99	0.4991160E-04	ZR-97	0.1583365E-06
91	W-185	0.4460184E-04	CE-143	0.1370020E-06
92	I-134	0.4300893E-04	PM-149	0.1261595E-06
93	TE-127	0.3680289E-04	IN-115M	0.1049205E-06
94	ND-149	0.2423895E-04	Y-93	0.7582310E-07
95	TE-129	0.2016894E-04	NP-239	0.7175584E-07
96	PB-204M	0.1939562E-04	SM-153	0.6212400E-07
97	IN-115M	0.1311507E-04	GD-159	0.2867260E-07
98	NB-97	0.1177966E-04	Y-92	0.2548676E-07
99	Y-91M	0.8641608E-05	ND-149	0.9695579E-08
100	TC-99M	0.1529205E-05	NB-97	0.4711861E-08
101	RH-103M	0.7768150E-06	Y-91M	0.3456643E-08

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = OVARIES

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
1	PU-239	0.2176467E 03	SR-90	0.1908106E 01
2	PU-240	0.2171915E 03	PB-210	0.5301245E 00
3	PU-238	0.1840500E 03	CS-134	0.7592928E-01
4	PU-241	0.2694068E 01	CS-137	0.4385849E-01
5	SR-90	0.2544142E 01	PU-239	0.2611759E-01
6	PB-210	0.1921701E 01	PU-240	0.2606297E-01
7	EU-152	0.9794879E-01	PU-238	0.2208599E-01
8	CE-144	0.6592041E-01	NA-22	0.1869029E-01
9	CS-134	0.5694696E-01	I-129	0.1304285E-01
10	CS-137	0.3289387E-01	CA-45	0.8877035E-02
11	ZR-95	0.1620798E-01	SR-89	0.8813635E-02
12	NA-22	0.1401772E-01	CL-36	0.8007091E-02
13	EU-155	0.1333808E-01	CS-136	0.7592931E-02
14	SR-89	0.1175152E-01	P-32	0.7419035E-02
15	FE-59	0.1101888E-01	CS-135	0.4906204E-02
16	I-129	0.9782135E-02	CO-60	0.4539829E-02
17	Y-91	0.9084973E-02	RB-87	0.4300892E-02
18	CA-45	0.8137282E-02	FE-59	0.3672960E-02
19	BA-140	0.7317673E-02	I-131	0.3551156E-02
20	SM-151	0.7192045E-02	TE-129M	0.2920358E-02
21	PM-147	0.7016025E-02	S-35	0.2634482E-02
22	NB-93M	0.6355762E-02	NA-24	0.1720357E-02
23	P-32	0.6231990E-02	HG-203	0.1632747E-02
24	CO-60	0.6053109E-02	ZN-65	0.1544150E-02
25	CL-36	0.6005317E-02	TE-132	0.1311506E-02
26	CS-136	0.5694699E-02	BA-140	0.1306728E-02
27	CD-115M	0.5668148E-02	TE-127M	0.1104427E-02
28	ZN-65	0.4632447E-02	K-42	0.8835411E-03
29	NB-95	0.4535846E-02	MN-54	0.8773815E-03
30	TE-129M	0.4438940E-02	MO-99	0.8257707E-03
31	SB-125	0.3715969E-02	I-133	0.7760720E-03
32	CS-135	0.3679653E-02	TL-204	0.5973463E-03
33	RB-87	0.3225669E-02	C-14	0.5734523E-03
34	RU-106	0.2890198E-02	TE-131M	0.4884962E-03
35	I-131	0.2663367E-02	TE-125M	0.4778770E-03
36	MN-54	0.2632145E-02	SB-125	0.4128853E-03
37	ZR-93	0.2628322E-02	I-135	0.3865489E-03
38	IN-115	0.2166375E-02	SN-125	0.3743365E-03
39	SN-125	0.2096285E-02	PU-241	0.3232881E-03
40	TE-132	0.1993489E-02	RU-106	0.3211331E-03
41	S-35	0.1975861E-02	FE-55	0.3195934E-03
42	TE-127M	0.1678728E-02	SR-91	0.2676109E-03
43	CE-141	0.1672569E-02	AU-196	0.2637878E-03
44	BI-207	0.1380534E-02	I-132	0.1751153E-03
45	HG-203	0.1371507E-02	AU-198	0.1601418E-03
46	NA-24	0.1290268E-02	TL-201	0.1543540E-03
47	ND-147	0.1178763E-02	H-3	0.1274339E-03
48	PR-143	0.1146904E-02	SR-92	0.9111511E-04
49	SC-48	0.9929221E-03	RU-103	0.8690984E-04
50	FE-55	0.9587801E-03	I-134	0.5734524E-04
51	LA-140	0.8474349E-03	CD-115M	0.5668150E-04

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = OVARIES

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
52	AU-196	0.7913639E-03	RH-105	0.5649564E-04
53	RU-103	0.7821887E-03	BI-207	0.5309744E-04
54	TE-131M	0.7425142E-03	TC-99	0.4991160E-04
55	TE-125M	0.7263729E-03	PD-109	0.4549386E-04
56	MO-99	0.6709388E-03	PB-203	0.4055790E-04
57	K-42	0.6626558E-03	CU-64	0.3939829E-04
58	TL-204	0.6371692E-03	EU-152	0.3917952E-04
59	Y-90	0.6332397E-03	W-187	0.3610624E-04
60	I-133	0.5820540E-03	CE-144	0.2636816E-04
61	AU-198	0.4804253E-03	TE-127	0.2421242E-04
62	C-14	0.4300892E-03	MN-56	0.2219471E-04
63	CD-115	0.4146909E-03	W-181	0.2123897E-04
64	ZR-97	0.3958412E-03	IN-115	0.1733098E-04
65	BE-7	0.3809740E-03	W-185	0.1486728E-04
66	SR-91	0.3568146E-03	TE-129	0.1326905E-04
67	CE-143	0.3425048E-03	AG-111	0.1274338E-04
68	AG-111	0.3313280E-03	AS-77	0.1223364E-04
69	PM-149	0.3153987E-03	RU-105	0.7263729E-05
70	I-135	0.2899116E-03	ZR-95	0.6483190E-05
71	Y-93	0.1895578E-03	PB-204M	0.5350517E-05
72	NP-239	0.1793897E-03	EU-155	0.5335231E-05
73	CR-51	0.1765489E-03	CD-115	0.4146909E-05
74	TL-201	0.1646443E-03	Y-91	0.3633989E-05
75	SM-153	0.1553100E-03	CR-51	0.3530977E-05
76	PB-203	0.1470225E-03	BE-7	0.3047791E-05
77	I-132	0.1313364E-03	SM-151	0.2876818E-05
78	H-3	0.1274339E-03	PM-147	0.2806410E-05
79	SR-92	0.1214868E-03	NB-93M	0.2542305E-05
80	AS-77	0.1101027E-03	NB-95	0.1814338E-05
81	W-187	0.1083188E-03	TC-99M	0.1529205E-05
82	RH-105	0.9886739E-04	ZR-93	0.1051329E-05
83	PD-109	0.7961424E-04	CE-141	0.6690274E-06
84	GD-159	0.7168151E-04	ND-147	0.4715051E-06
85	MN-56	0.6658415E-04	PR-143	0.4587616E-06
86	RU-105	0.6537356E-04	RH-103M	0.4438943E-06
87	W-181	0.6371693E-04	SC-48	0.3971688E-06
88	Y-92	0.6371690E-04	LA-140	0.3389739E-06
89	CU-64	0.5487620E-04	Y-90	0.2532959E-06
90	TC-99	0.4991160E-04	ZR-97	0.1583365E-06
91	W-185	0.4460184E-04	CE-143	0.1370020E-06
92	I-134	0.4300893E-04	PM-149	0.1261595E-06
93	TE-127	0.3680289E-04	IN-115M	0.1049205E-06
94	ND-149	0.2423895E-04	Y-93	0.7582310E-07
95	TE-129	0.2016894E-04	NP-239	0.7175584E-07
96	PB-204M	0.1939562E-04	SM-153	0.6212400E-07
97	IN-115M	0.1311507E-04	GD-159	0.2867260E-07
98	NB-97	0.1177966E-04	Y-92	0.2548676E-07
99	Y-91M	0.8641608E-05	ND-149	0.9695579E-08
100	TC-99M	0.1529205E-05	NB-97	0.4711861E-08
101	RH-103M	0.7768150E-06	Y-91M	0.3456643E-08

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 2555C. ORGAN = SPLEEN

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
1	PU-239	0.2176467E 03	SR-90	0.1908106E 01
2	PU-240	0.2171915E 03	PB-210	0.5301245E 00
3	PU-238	0.1840500E 03	CS-134	0.8560473E-01
4	PU-241	0.2694068E 01	CS-137	0.7589811E-01
5	SR-90	0.2544142E 01	PU-239	0.2611759E-01
6	PB-210	0.1921701E 01	PU-240	0.2606297E-01
7	EU-152	0.9794879E-01	PU-238	0.2208599E-01
8	CE-144	0.6592041E-01	NA-22	0.1869029E-01
9	CS-134	0.6505960E-01	CS-135	0.1367815E-01
10	CS-137	0.5768257E-01	TE-129M	0.1319599E-01
11	FE-59	0.3615193E-01	I-129	0.1304285E-01
12	NB-93M	0.2430093E-01	FE-59	0.1205065E-01
13	TE-129M	0.2005791E-01	HG-203	0.1040453E-01
14	ZN-65	0.1977771E-01	CA-45	0.8877035E-02
15	IN-115	0.1725629E-01	SR-89	0.8813635E-02
16	ZR-95	0.1721823E-01	CL-36	0.8007091E-02
17	NA-22	0.1401772E-01	TE-127M	0.7782243E-02
18	EU-155	0.1333808E-01	P-32	0.7419035E-02
19	ZR-93	0.1256157E-01	CS-136	0.7052660E-02
20	TE-127M	0.1182901E-01	RB-87	0.6851759E-02
21	SR-89	0.1175152E-01	ZN-65	0.6592568E-02
22	CS-135	0.1039540E-01	I-131	0.3551156E-02
23	I-129	0.9782135E-02	TE-125M	0.2960639E-02
24	Y-91	0.9084973E-02	TE-132	0.2943721E-02
25	CA-45	0.8137282E-02	S-35	0.2634482E-02
26	SM-151	0.7192045E-02	FE-55	0.2133352E-02
27	PM-147	0.7016025E-02	NA-24	0.1720357E-02
28	FE-55	0.6400052E-02	K-42	0.1319598E-02
29	P-32	0.6231990E-02	TE-131M	0.1015076E-02
30	CL-36	0.6005317E-02	CO-60	0.9450358E-03
31	NB-95	0.5718261E-02	MN-54	0.8773815E-03
32	CD-115M	0.5668148E-02	MO-99	0.8257707E-03
33	CS-136	0.5360022E-02	I-133	0.7760720E-03
34	HG-203	0.5202264E-02	CU-64	0.6039704E-03
35	RB-87	0.5138822E-02	TL-204	0.5973463E-03
36	TE-125M	0.4500169E-02	C-14	0.5734523E-03
37	TE-132	0.4474454E-02	SB-125	0.4128853E-03
38	SB-125	0.3715969E-02	I-135	0.3865489E-03
39	BI-207	0.3628895E-02	SN-125	0.3743365E-03
40	RU-106	0.2890198E-02	PU-241	0.3232881E-03
41	I-131	0.2663367E-02	RU-106	0.3211331E-03
42	MN-54	0.2632145E-02	SR-91	0.2676109E-03
43	SN-125	0.2096285E-02	AU-198	0.2341018E-03
44	S-35	0.1975861E-02	RH-105	0.2282229E-03
45	CE-141	0.1672569E-02	PD-109	0.1954020E-03
46	TE-131M	0.1542916E-02	I-132	0.1751153E-03
47	NA-24	0.1290268E-02	AU-196	0.1744662E-03
48	CO-60	0.1260048E-02	TL-201	0.1543540E-03
49	ND-147	0.1178763E-02	BI-207	0.1395729E-03
50	PR-143	0.1146904E-02	IN-115	0.1380503E-03
51	SC-48	0.9929221E-03	H-3	0.1274339E-03

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)
GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = SPLEEN
SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
52	K-42	0.9896993E-03	TE-127	0.9896995E-04
53	CU-64	0.9059557E-03	SR-92	0.9111511E-04
54	LA-140	0.8474349E-03	RU-103	0.8690984E-04
55	RU-103	0.7821887E-03	I-134	0.5734524E-04
56	AU-198	0.7023055E-03	CD-115M	0.5668150E-04
57	ZR-97	0.6756603E-03	TC-99	0.4991160E-04
58	MO-99	0.6709388E-03	PB-203	0.4055790E-04
59	TL-204	0.6371692E-03	EU-152	0.3917952E-04
60	Y-90	0.6332397E-03	TE-129	0.3666962E-04
61	I-133	0.5820540E-03	W-187	0.3610624E-04
62	AU-196	0.5233986E-03	CE-144	0.2636816E-04
63	C-14	0.4300892E-03	MN-56	0.2219471E-04
64	CD-115	0.4146909E-03	W-181	0.2123897E-04
65	RH-105	0.3993900E-03	W-185	0.1486728E-04
66	SR-91	0.3568146E-03	AG-111	0.1274338E-04
67	CE-143	0.3425048E-03	AS-77	0.1223364E-04
68	PD-109	0.3419535E-03	NB-93M	0.9720374E-05
69	AG-111	0.3313280E-03	BA-140	0.8120608E-05
70	PM-149	0.3153987E-03	RU-105	0.7263729E-05
71	I-135	0.2899116E-03	ZR-95	0.6887293E-05
72	Y-93	0.1895578E-03	PB-204M	0.5350517E-05
73	NP-239	0.1793897E-03	EU-155	0.5335231E-05
74	CR-51	0.1765489E-03	ZR-93	0.5024628E-05
75	TL-201	0.1646443E-03	CD-115	0.4146909E-05
76	SM-153	0.1553100E-03	Y-91	0.3633989E-05
77	TE-127	0.1504343E-03	CR-51	0.3530977E-05
78	PB-203	0.1470225E-03	SM-151	0.2876818E-05
79	I-132	0.1313364E-03	PM-147	0.2806410E-05
80	H-3	0.1274339E-03	NB-95	0.2287304E-05
81	BE-7	0.1243468E-03	RH-103M	0.1735780E-05
82	SR-92	0.1214868E-03	TC-99M	0.1529205E-05
83	AS-77	0.1101027E-03	BE-7	0.9947744E-06
84	W-187	0.1083188E-03	CE-141	0.6690274E-06
85	IN-115M	0.7634220E-04	IN-115M	0.6107377E-06
86	GD-159	0.7168151E-04	ND-147	0.4715051E-06
87	MN-56	0.6658415E-04	PR-143	0.4587616E-06
88	RU-105	0.6537356E-04	SC-48	0.3971688E-06
89	W-181	0.6371693E-04	LA-140	0.3389739E-06
90	Y-92	0.6371690E-04	ZR-97	0.2702641E-06
91	TE-129	0.5573782E-04	Y-90	0.2532959E-06
92	TC-99	0.4991160E-04	CE-143	0.1370020E-06
93	BA-140	0.4547539E-04	PM-149	0.1261595E-06
94	W-185	0.4460184E-04	Y-93	0.7582310E-07
95	I-134	0.4300893E-04	NP-239	0.7175584E-07
96	NB-97	0.2588444E-04	SM-153	0.6212400E-07
97	ND-149	0.2423895E-04	GD-159	0.2867260E-07
98	PB-204M	0.1939562E-04	Y-92	0.2548676E-07
99	Y-91M	0.8641608E-05	NB-97	0.1035378E-07
100	RH-103M	0.3037615E-05	ND-149	0.9695579E-08
101	TC-99M	0.1529205E-05	Y-91M	0.3456643E-08

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)
GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = TESTES
SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
1	PU-239	0.2176467E 03	SR-90	0.1908106E 01
2	PU-240	0.2171915E 03	PB-210	0.5301245E 00
3	PU-238	0.1840500E 03	CS-134	0.7592928E-01
4	PU-241	0.2694068E 01	CS-137	0.4385849E-01
5	SR-90	0.2544142E 01	PU-239	0.2611759E-01
6	PB-210	0.1921701E 01	PU-240	0.2606297E-01
7	EU-152	0.9794879E-01	PU-238	0.2208599E-01
8	CE-144	0.6592041E-01	TE-129M	0.1965647E-01
9	CS-134	0.5694696E-01	NA-22	0.1869029E-01
10	CS-137	0.3289387E-01	S-35	0.1320383E-01
11	TE-129M	0.2882950E-01	I-129	0.1304785E-01
12	ZR-95	0.1620798E-01	CA-45	0.8877035E-02
13	NA-22	0.1401772E-01	SR-89	0.8813635E-02
14	EU-155	0.1333808E-01	CL-36	0.8007091E-02
15	SR-89	0.1175152E-01	CS-136	0.7592931E-02
16	FE-59	0.1101888E-01	P-32	0.7419035E-02
17	S-35	0.9953655E-02	CS-135	0.4906204E-02
18	I-129	0.9782135E-02	CO-60	0.4539829E-02
19	Y-91	0.9084973E-02	RB-87	0.4300892E-02
20	CA-45	0.8137282E-02	TE-125M	0.3917050E-02
21	BA-140	0.7317673E-02	TE-132	0.3769271E-02
22	SM-151	0.7192045E-02	FE-59	0.3672960E-02
23	PM-147	0.7016025E-02	I-131	0.3551156E-02
24	NB-93M	0.6355762E-02	NA-24	0.1720357E-02
25	P-32	0.6231990E-02	HG-203	0.1632747E-02
26	CO-60	0.6053109E-02	ZN-65	0.1531495E-02
27	CL-36	0.6005317E-02	BA-140	0.1306728E-02
28	TE-125M	0.5745005E-02	TE-127M	0.1104427E-02
29	CS-136	0.5694699E-02	K-42	0.8835411E-03
30	CD-115M	0.5668148E-02	MN-54	0.8773815E-03
31	TE-132	0.5528264E-02	MO-99	0.8257707E-03
32	ZN-65	0.4594482E-02	I-133	0.7760720E-03
33	NB-95	0.4535846E-02	TL-204	0.5973463E-03
34	SB-125	0.3715969E-02	C-14	0.5734523E-03
35	CS-135	0.3679653E-02	TE-131M	0.4884962E-03
36	RB-87	0.3225669E-02	SB-125	0.4128853E-03
37	RU-106	0.2890198E-02	I-135	0.3865489E-03
38	I-131	0.2663367E-02	SN-125	0.3743365E-03
39	MN-54	0.2632145E-02	PU-241	0.3232881E-03
40	ZR-93	0.2628322E-02	RU-106	0.3211331E-03
41	IN-115	0.2166375E-02	FE-55	0.3195934E-03
42	SN-125	0.2096285E-02	SR-91	0.2676109E-03
43	TE-127M	0.1678728E-02	AU-196	0.2637878E-03
44	CE-141	0.1672569E-02	I-132	0.1751153E-03
45	BI-207	0.1380534E-02	TE-127	0.1666527E-03
46	HG-203	0.1371507E-02	AU-198	0.1601418E-03
47	NA-24	0.1290268E-02	TL-201	0.1543540E-03
48	ND-147	0.1178763E-02	H-3	0.1274339E-03
49	PR-143	0.1146904E-02	SR-92	0.9111511E-04
50	SC-48	0.9929221E-03	RU-103	0.8690984E-04
51	FE-55	0.9587801E-03	I-134	0.5734524E-04

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = TESTES

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
52	LA-140	0.8474349E-03	CD-115M	0.5668150E-04
53	AU-196	0.7913639E-03	RH-105	0.5649564E-04
54	RU-103	0.7821887E-03	TE-129	0.5448257E-04
55	TE-131M	0.7425142E-03	BI-207	0.5309744E-04
56	MO-99	0.6709388E-03	TC-99	0.4991160E-04
57	K-42	0.6626558E-03	PD-109	0.4549386E-04
58	TL-204	0.6371692E-03	PB-203	0.4055790E-04
59	Y-90	0.6332397E-03	CU-64	0.3939829E-04
60	I-133	0.5820540E-03	EU-152	0.3917952E-04
61	AU-198	0.4804253E-03	W-187	0.3610624E-04
62	C-14	0.4300892E-03	CE-144	0.2636816E-04
63	CD-115	0.4146909E-03	MN-56	0.2219471E-04
64	ZR-97	0.3958412E-03	W-181	0.2123897E-04
65	BE-7	0.3809740E-03	IN-115	0.1733098E-04
66	SR-91	0.3568146E-03	W-185	0.1486728E-04
67	CE-143	0.3425048E-03	AG-111	0.1274338E-04
68	AG-111	0.3313280E-03	AS-77	0.1223364E-04
69	PM-149	0.3153987E-03	RU-105	0.7263729E-05
70	I-135	0.2899116E-03	ZR-95	0.6483190E-05
71	TE-127	0.2444237E-03	PB-204M	0.5350517E-05
72	Y-93	0.1895578E-03	EU-155	0.5335231E-05
73	NP-239	0.1793897E-03	CD-115	0.4146909E-05
74	CR-51	0.1765489E-03	Y-91	0.3633989E-05
75	TL-201	0.1646443E-03	CR-51	0.3530977E-05
76	SM-153	0.1553100E-03	BE-7	0.3047791E-05
77	PB-203	0.1470225E-03	SM-151	0.2876818E-05
78	I-132	0.1313364E-03	PM-147	0.2806410E-05
79	H-3	0.1274339E-03	NB-93M	0.2542305E-05
80	SR-92	0.1214868E-03	NB-95	0.1814338E-05
81	AS-77	0.1101027E-03	TC-99M	0.1529205E-05
82	W-187	0.1083188E-03	ZR-93	0.1051329E-05
83	RH-105	0.9886739E-04	CE-141	0.6690274E-06
84	TE-129	0.7990780E-04	ND-147	0.4715051E-06
85	PD-109	0.7961424E-04	PR-143	0.4587616E-06
86	GD-159	0.7168151E-04	RH-103M	0.4438943E-06
87	MN-56	0.6658415E-04	SC-48	0.3971688E-06
88	RU-105	0.6537356E-04	LA-140	0.3389739E-06
89	W-181	0.6371693E-04	Y-90	0.2532959E-06
90	Y-92	0.6371690E-04	ZR-97	0.1583365E-06
91	CU-64	0.5487620E-04	CE-143	0.1370020E-06
92	TC-99	0.4991160E-04	PM-149	0.1261595E-06
93	W-185	0.4460184E-04	IN-115M	0.1049205E-06
94	I-134	0.4300893E-04	Y-93	0.7582310E-07
95	ND-149	0.2423895E-04	NP-239	0.7175584E-07
96	PB-204M	0.1939562E-04	SM-153	0.6212400E-07
97	IN-115M	0.1311507E-04	GD-159	0.2867260E-07
98	NB-97	0.1177966E-04	Y-92	0.2548676E-07
99	Y-91M	0.8641608E-05	ND-149	0.9695579E-08
100	TC-99M	0.1529205E-05	NB-97	0.4711861E-08
101	RH-103M	0.7768150E-06	Y-91M	0.3456643E-08

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = THYROID

SOLUBLE

	INHALATION		INGESTION	
NO.	NUCLIDE	REM/MICROCI	NUCLIDE	REM/MICROCI
1	PU-239	0.2176467E 03	I-129	0.1354111E 02
2	PU-240	0.2171915E 03	I-131	0.2522365E 01
3	PU-238	0.1840500E 03	SR-90	0.1908106E 01
4	I-129	0.1038152E 02	I-133	0.6779212E 00
5	PU-241	0.2694068E 01	PB-210	0.5301245E 00
6	SR-90	0.2544142E 01	I-135	0.2101008E 00
7	I-131	0.1933813E 01	I-132	0.9098113E-01
8	PB-210	0.1921701E 01	CS-134	0.7592928E-01
9	I-133	0.5197396E 00	CS-137	0.4385849E-01
10	I-135	0.1610773E 00	I-134	0.4259737E-01
11	EU-152	0.9794879E-01	PU-239	0.2611759E-01
12	I-132	0.6975216E-01	PU-240	0.2606297E-01
13	CE-144	0.6592041E-01	PU-238	0.2208599E-01
14	CS-134	0.5694696E-01	NA-22	0.1869029E-01
15	CS-137	0.3289387E-01	CA-45	0.8877035E-02
16	I-134	0.3265798E-01	SR-89	0.8813635E-02
17	ZN-65	0.1977771E-01	CL-36	0.8007091E-02
18	ZR-95	0.1620798E-01	CS-136	0.7592931E-02
19	NA-22	0.1401772E-01	P-32	0.7419035E-02
20	EU-155	0.1333808E-01	ZN-65	0.6592568E-02
21	SR-89	0.1175152E-01	TE-129M	0.5805664E-02
22	FE-59	0.1101888E-01	CS-135	0.4906204E-02
23	Y-91	0.9084973E-02	CO-60	0.4539829E-02
24	TE-129M	0.8824617E-02	RB-87	0.4300892E-02
25	CA-45	0.8137282E-02	FE-59	0.3672960E-02
26	BA-140	0.7317673E-02	TE-127M	0.2994225E-02
27	SM-151	0.7192045E-02	S-35	0.2634482E-02
28	PM-147	0.7016025E-02	TE-132	0.2135640E-02
29	NB-93M	0.6355762E-02	NA-24	0.1720357E-02
30	P-32	0.6231990E-02	HG-203	0.1632747E-02
31	CO-60	0.6053109E-02	BA-140	0.1306728E-02
32	CL-36	0.6005317E-02	TE-125M	0.1031744E-02
33	CS-136	0.5694699E-02	TE-131M	0.9126966E-03
34	CD-115M	0.5668148E-02	K-42	0.8835411E-03
35	TE-127M	0.4551221E-02	MN-54	0.8773815E-03
36	NB-95	0.4535846E-02	MO-99	0.8257707E-03
37	CS-135	0.3679653E-02	TL-204	0.5973463E-03
38	TE-132	0.3246173E-02	C-14	0.5734523E-03
39	RB-87	0.3225669E-02	PU-241	0.3232881E-03
40	RU-106	0.2890198E-02	RU-106	0.3211331E-03
41	MN-54	0.2632145E-02	FE-55	0.3195934E-03
42	ZR-93	0.2628322E-02	SR-91	0.2676109E-03
43	S-35	0.1975861E-02	AU-196	0.2637878E-03
44	CE-141	0.1672569E-02	SN-125	0.1878787E-03
45	TE-125M	0.1568252E-02	AU-198	0.1601418E-03
46	TE-131M	0.1387299E-02	TL-201	0.1543540E-03
47	BI-207	0.1380534E-02	H-3	0.1274339E-03
48	HG-203	0.1371507E-02	TE-127	0.1067820E-03
49	NA-24	0.1290268E-02	SR-92	0.9111511E-04
50	ND-147	0.1178763E-02	RU-103	0.8690984E-04
51	PR-143	0.1146904E-02	CD-115M	0.5668150E-04

APPENDIX IX, continued

LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DOSE/UNIT INTAKE)

GAMMA = 20.5 TAU = 0. T = 25550. ORGAN = THYROID

SOLUBLE

NO.	INHALATION NUCLIDE	INHALATION REM/MICROCI	INGESTION NUCLIDE	INGESTION REM/MICROCI
52	SN-125	0.1052120E-02	RH-105	0.5649564E-04
53	SC-48	0.9929221E-03	BI-207	0.5309744E-04
54	FE-55	0.9587801E-03	TC-99	0.4991160E-04
55	LA-140	0.8474349E-03	PD-109	0.4549386E-04
56	AU-196	0.7913639E-03	PB-203	0.4055790E-04
57	RU-103	0.7821887E-03	CU-64	0.3939829E-04
58	IN-115	0.6868683E-03	EU-152	0.3917952E-04
59	MO-99	0.6709388E-03	TE-129	0.3679650E-04
60	K-42	0.6626558E-03	W-187	0.3610624E-04
61	TL-204	0.6371692E-03	CE-144	0.2636816E-04
62	Y-90	0.6332397E-03	MN-56	0.2219471E-04
63	AU-198	0.4804253E-03	W-181	0.2123897E-04
64	C-14	0.4300892E-03	W-185	0.1486728E-04
65	CD-115	0.4146909E-03	AG-111	0.1274338E-04
66	ZR-97	0.3958412E-03	AS-77	0.1223364E-04
67	BE-7	0.3809740E-03	RU-105	0.7263729E-05
68	SR-91	0.3568146E-03	ZR-95	0.6483190E-05
69	CE-143	0.3425048E-03	IN-115	0.5494947E-05
70	AG-111	0.3313280E-03	PB-204M	0.5350517E-05
71	PM-149	0.3153987E-03	EU-155	0.5335231E-05
72	CR-51	0.2471914E-03	CR-51	0.4836357E-05
73	Y-93	0.1895578E-03	CD-115	0.4146909E-05
74	NP-239	0.1793897E-03	Y-91	0.3633989E-05
75	TL-201	0.1646443E-03	BE-7	0.3047791E-05
76	TE-127	0.1623087E-03	SM-151	0.2876818E-05
77	SM-153	0.1553100E-03	PM-147	0.2806410E-05
78	PB-203	0.1470225E-03	NB-93M	0.2542305E-05
79	H-3	0.1274339E-03	SB-125	0.2424240E-05
80	SR-92	0.1214868E-03	NB-95	0.1814338E-05
81	AS-77	0.1101027E-03	TC-99M	0.1529205E-05
82	W-187	0.1083188E-03	ZR-93	0.1051329E-05
83	RH-105	0.9886739E-04	CE-141	0.6690274E-06
84	PD-109	0.7961424E-04	ND-147	0.4715051E-06
85	GD-159	0.7168151E-04	PR-143	0.4587616E-06
86	MN-56	0.6658415E-04	RH-103M	0.4438943E-06
87	RU-105	0.6537356E-04	SC-48	0.3971688E-06
88	W-181	0.6371693E-04	LA-140	0.3389739E-06
89	Y-92	0.6371690E-04	Y-90	0.2532959E-06
90	TE-129	0.5593069E-04	ZR-97	0.1583365E-06
91	CU-64	0.5487620E-04	CE-143	0.1370020E-06
92	TC-99	0.4991160E-04	PM-149	0.1261595E-06
93	W-185	0.4460184E-04	IN-115M	0.1169792E-06
94	ND-149	0.2423895E-04	Y-93	0.7582310E-07
95	SB-125	0.2154880E-04	NP-239	0.7175584E-07
96	PB-204M	0.1939562E-04	SM-153	0.6212400E-07
97	IN-115M	0.1462240E-04	GD-159	0.2867260E-07
98	NB-97	0.1177966E-04	Y-92	0.2548676E-07
99	Y-91M	0.8641608E-05	ND-149	0.9695579E-08
100	TC-99M	0.1529205E-05	NB-97	0.4711861E-08
101	RH-103M	0.7768150E-06	Y-91M	0.3456643E-08

APPENDIX X

COMPOSITE LISTINGS OF RADIONUCLIDES BASED ON DOSES TO THE CRITICAL ORGANS FROM 1 MICROCURIE INTAKES

GAMMA = 20.5 TAU = 0.0 T = 365

	SOLUBLE				INSOLUBLE			
	INGESTION		INHALATION		INGESTION		INHALATION	
NO.	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED
1	I-129	0.100E 01	PU-238	0.100E 01	CE-144	0.100E 01	PU-238	0.100E 01
2	PB-210	0.821E 00	PU-239	0.968E 00	RU-106	0.100E 01	PU-239	0.933E 00
3	I-131	0.221E 00	PU-240	0.968E 00	K-42	0.499E 00	PU-240	0.933E 00
4	SR-90	0.129E 00	PB-210	0.222E 00	BA-140	0.499E 00	PB-210	0.251E 00
5	I-133	0.595E-01	I-129	0.514E-01	LA-140	0.499E 00	PU-241	0.911E-01
6	CS-134	0.392E-01	PU-241	0.489E-01	SN-125	0.499E 00	RU-106	0.115E-01
7	CE-144	0.342E-01	SR-90	0.116E-01	TE-129M	0.499E 00	SR-90	0.111E-01
8	RU-106	0.342E-01	I-131	0.114E-01	P-32	0.499E 00	CE-144	0.101E-01
9	CA-45	0.314E-01	CE-144	0.528E-02	TE-132	0.499E 00	NA-22	0.746E-02
10	CS-137	0.225E-01	I-133	0.307E-02	Y-90	0.499E 00	CO-60	0.701E-02
11	P-32	0.195E-01	Y-91	0.224E-02	ZR-97	0.499E 00	CS-134	0.525E-02
12	I-135	0.184E-01	CD-115M	0.215E-02	SC-48	0.333E 00	BI-207	0.445E-02
13	HG-203	0.178E-01	CS-134	0.198E-02	SR-89	0.333E 00	CS-137	0.413E-02
14	LA-140	0.171E-01	CA-45	0.196E-02	NA-22	0.333E 00	EU-152	0.330E-02
15	SN-125	0.171E-01	SR-89	0.120E-02	CD-115M	0.333E 00	CL-36	0.264E-02
16	Y-90	0.171E-01	EU-152	0.119E-02	NA-24	0.333E 00	TL-204	0.236E-02
17	ZR-97	0.171E-01	CS-137	0.113E-02	CO-60	0.333E 00	SB-125	0.232E-02
18	SR-89	0.133E-01	P-32	0.112E-02	PU-238	0.333E 00	Y-91	0.222E-02
19	SC-48	0.114E-01	TE-129M	0.105E-02	PU-239	0.333E 00	TE-129M	0.208E-02
20	BA-140	0.114E-01	HG-203	0.102E-02	PU-240	0.333E 00	ZR-95	0.208E-02
21	CD-115M	0.114E-01	I-135	0.950E-03	Y-91	0.333E 00	ZR-93	0.203E-02
22	CD-115	0.114E-01	RU-106	0.844E-03	Y-93	0.333E 00	SR-89	0.189E-02
23	TE-129M	0.114E-01	SN-125	0.631E-03	AG-111	0.250E 00	CD-115M	0.187E-02
24	TE-132	0.114E-01	Y-90	0.631E-03	MO-99	0.250E 00	MN-54	0.180E-02
25	Y-91	0.114E-01	ZR-97	0.631E-03	SR-90	0.250E 00	IN-115	0.173E-02
26	Y-93	0.114E-01	TE-127M	0.621E-03	CD-115	0.250E 00	TE-127M	0.171E-02
27	NA-22	0.984E-02	BA-140	0.606E-03	CE-143	0.250E 00	BA-140	0.156E-02
28	AG-111	0.853E-02	ZR-95	0.567E-03	CS-134	0.250E 00	FE-59	0.133E-02
29	CE-143	0.853E-02	ZN-65	0.511E-03	TE-131M	0.250E 00	ZN-65	0.112E-02
30	PB-204M	0.853E-02	LA-140	0.507E-03	PB-204M	0.250E 00	TC-99	0.956E-03
31	PM-149	0.853E-02	NA-22	0.496E-03	CS-137	0.250E 00	RB-87	0.915E-03
32	I-132	0.800E-02	PM-147	0.457E-03	PM-149	0.250E 00	P-32	0.850E-03
33	AU-198	0.684E-02	BI-207	0.443E-03	I-133	0.250E 00	EU-155	0.847E-03
34	CO-60	0.684E-02	FE-59	0.426E-03	AU-198	0.200E 00	I-129	0.834E-03
35	PR-143	0.684E-02	SC-48	0.422E-03	SR-91	0.200E 00	SN-125	0.816E-03
36	S-35	0.668E-02	Y-93	0.422E-03	TE-127M	0.200E 00	RU-103	0.796E-03
37	TE-127M	0.611E-02	I-132	0.411E-03	PR-143	0.200E 00	Y-90	0.752E-03
38	BI-207	0.569E-02	TE-132	0.362E-03	FE-59	0.200E 00	ZR-97	0.752E-03
39	ND-147	0.568E-02	S-35	0.340E-03	BI-207	0.167E 00	NB-95	0.680E-03
40	TE-131M	0.568E-02	EU-155	0.335E-03	SR-92	0.167E 00	CS-135	0.671E-03
41	FE-59	0.568E-02	CD-115	0.317E-03	ND-147	0.167E 00	PM-147	0.641E-03
42	Y-92	0.568E-02	IN-115	0.282E-03	CL-36	0.167E 00	W-185	0.615E-03
43	ZR-95	0.568E-02	CE-143	0.281E-03	CS-136	0.167E 00	K-42	0.565E-03
44	SR-91	0.488E-02	AU-198	0.253E-03	TL-204	0.167E 00	LA-140	0.565E-03
45	SR-92	0.488E-02	ND-147	0.253E-03	W-187	0.167E 00	TE-132	0.565E-03
46	W-187	0.488E-02	CO-60	0.253E-03	Y-92	0.167E 00	CA-45	0.560E-03
47	AS-77	0.427E-02	TE-131M	0.253E-03	I-131	0.167E 00	C-14	0.549E-03
48	SM-153	0.427E-02	PB-204M	0.253E-03	ZR-95	0.167E 00	HG-203	0.544E-03
49	EU-152	0.427E-02	PM-149	0.253E-03	I-135	0.143E 00	W-181	0.531E-03
50	GD-159	0.427E-02	PR-143	0.253E-03	PD-109	0.143E 00	TE-125M	0.527E-03
51	RU-103	0.427E-02	Y-92	0.253E-03	AS-77	0.125E 00	SC-48	0.451E-03

APPENDIX X, continued

COMPOSITE LISTINGS OF RADIONUCLIDES BASED ON DOSES TO THE CRITICAL ORGANS FROM 1 MICROCURIE INTAKES

GAMMA = 20.5 TAU = 0.0 T = 365

	SOLUBLE				INSOLUBLE			
	INGESTION		INHALATION		INGESTION		INHALATION	
NO.	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED
52	CL-36	0.421E-02	TE-125M	0.236E-03	SM-153	0.125E 00	NA-24	0.451E-03
53	CS-136	0.399E-02	CL-36	0.213E-03	EU-152	0.125E 00	Y-93	0.451E-03
54	IN-115	0.379E-02	CS-136	0.202E-03	GD-159	0.125E 00	CE-141	0.438E-03
55	CE-141	0.379E-02	MN-54	0.196E-03	RU-103	0.125E 00	SM-151	0.426E-03
56	PD-109	0.379E-02	SM-151	0.193E-03	IN-115	0.111E 00	CS-136	0.396E-03
57	I-134	0.374E-02	I-134	0.193E-03	CE-141	0.111E 00	PR-143	0.379E-03
58	SB-125	0.342E-02	NB-93M	0.184E-03	SB-125	0.100E 00	NB-93M	0.377E-03
59	MN-54	0.342E-02	CS-135	0.148E-03	AU-196	0.100E 00	CD-115	0.376E-03
60	MN-56	0.342E-02	ZR-93	0.143E-03	MN-54	0.100E 00	TE-131M	0.376E-03
61	NB-95	0.342E-02	AS-77	0.127E-03	MN-56	0.100E 00	MO-99	0.322E-03
62	NP-239	0.342E-02	SB-125	0.127E-03	NB-95	0.100E 00	CE-143	0.322E-03
63	TL-204	0.342E-02	SM-153	0.127E-03	TE-125M	0.100E 00	I-133	0.322E-03
64	W-185	0.342E-02	SR-91	0.127E-03	NP-239	0.100E 00	ND-147	0.299E-03
65	RH-105	0.342E-02	SR-92	0.127E-03	W-185	0.100E 00	AG-111	0.282E-03
66	RU-105	0.342E-02	CE-141	0.127E-03	HG-203	0.100E 00	AU-198	0.282E-03
67	CS-135	0.307E-02	NB-95	0.127E-03	RH-105	0.100E 00	PB-204M	0.282E-03
68	ZN-65	0.253E-02	PD-109	0.127E-03	RU-105	0.100E 00	PM-149	0.282E-03
69	TE-125M	0.233E-02	TL-204	0.127E-03	C-14	0.499E-01	S-35	0.271E-03
70	RB-87	0.225E-02	W-187	0.127E-03	CA-45	0.499E-01	SR-91	0.251E-03
71	PU-238	0.178E-02	GD-159	0.127E-03	TC-99	0.499E-01	I-135	0.226E-03
72	PU-239	0.173E-02	RU-103	0.127E-03	TE-127	0.499E-01	AS-77	0.226E-03
73	PU-240	0.173E-02	RB-87	0.114E-03	CS-135	0.499E-01	SM-153	0.226E-03
74	MO-99	0.172E-02	MO-99	0.968E-04	PB-210	0.499E-01	SR-92	0.226E-03
75	AU-196	0.171E-02	MN-56	0.844E-04	TL-201	0.499E-01	PD-109	0.226E-03
76	NA-24	0.171E-02	NP-239	0.844E-04	CU-64	0.499E-01	W-187	0.226E-03
77	PM-147	0.171E-02	W-185	0.844E-04	PM-147	0.499E-01	GD-159	0.226E-03
78	EU-155	0.171E-02	RH-105	0.844E-04	EU-155	0.499E-01	Y-92	0.226E-03
79	K-42	0.114E-02	RU-105	0.844E-04	RB-87	0.499E-01	I-131	0.226E-03
80	TC-99	0.114E-02	AU-196	0.631E-04	I-129	0.499E-01	MN-56	0.113E-03
81	ND-149	0.114E-02	NA-24	0.631E-04	ZN-65	0.499E-01	NP-239	0.113E-03
82	TE-127	0.114E-02	ND-149	0.422E-04	I-132	0.499E-01	RH-105	0.113E-03
83	TL-201	0.114E-02	TE-127	0.422E-04	S-35	0.333E-01	RU-105	0.113E-03
84	CU-64	0.114E-02	AG-111	0.404E-04	ND-149	0.333E-01	AU-196	0.109E-03
85	IN-115M	0.853E-03	K-42	0.362E-04	W-181	0.333E-01	H-3	0.998E-04
86	SM-151	0.853E-03	TC-99	0.362E-04	IN-115M	0.250E-01	TE-127	0.752E-04
87	NB-93M	0.853E-03	TL-201	0.362E-04	SM-151	0.250E-01	TL-201	0.752E-04
88	PB-203	0.853E-03	CU-64	0.362E-04	NB-93M	0.250E-01	I-132	0.752E-04
89	W-181	0.853E-03	FE-55	0.362E-04	PB-203	0.250E-01	FE-55	0.612E-04
90	TE-129	0.427E-03	IN-115M	0.317E-04	I-134	0.167E-01	BE-7	0.571E-04
91	ZR-93	0.427E-03	W-181	0.317E-04	TE-129	0.125E-01	CU-64	0.565E-04
92	NB-97	0.379E-03	PB-203	0.281E-04	ZR-93	0.125E-01	ND-149	0.451E-04
93	C-14	0.302E-03	C-14	0.152E-04	NB-97	0.111E-01	IN-115M	0.376E-04
94	FE-55	0.179E-03	BE-7	0.135E-04	H-3	0.100E-01	PB-203	0.376E-04
95	BE-7	0.171E-03	NB-97	0.127E-04	PU-241	0.100E-01	CR-51	0.305E-04
96	CR-51	0.171E-03	TE-129	0.127E-04	BE-7	0.499E-02	TE-129	0.226E-04
97	Y-91M	0.114E-03	CR-51	0.631E-05	CR-51	0.499E-02	I-134	0.226E-04
98	PU-241	0.874E-04	H-3	0.450E-05	FE-55	0.499E-02	NB-97	0.113E-04
99	H-3	0.668E-04	Y-91M	0.317E-05	TC-99M	0.333E-02	TC-99M	0.451E-05
100	TC-99M	0.568E-04	TC-99M	0.253E-05	Y-91M	0.333E-02	Y-91M	0.376E-05
101	RH-103M	0.342E-04	RH-103M	0.844E-06	RH-103M	0.100E-02	RH-103M	0.113E-05

APPENDIX X, continued

COMPOSITE LISTINGS OF RADIONUCLIDES BASED ON DOSES TO THE CRITICAL ORGANS FROM 1 MICROCURIE INTAKES

GAMMA = 20.5 TAU = 0.0 T = 25550

	SOLUBLE				INSOLUBLE			
	INGESTION		INHALATION		INGESTION		INHALATION	
NO.	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED
1	SR-90	0.100E 01	PU-239	0.100E 01	CE-144	0.100E 01	PU-238	0.100E 01
2	PB-210	0.657E 00	PU-240	0.100E 01	RU-106	0.100E 01	PU-239	0.941E 00
3	I-129	0.380E 00	PU-238	0.812E 00	K-42	0.499E 00	PU-240	0.941E 00
4	I-131	0.706E-01	PU-241	0.146E-01	BA-140	0.499E 00	PB-210	0.144E 00
5	PU-239	0.343E-01	PB-210	0.918E-02	LA-140	0.499E 00	SR-90	0.633E-02
6	PU-240	0.343E-01	SR-90	0.466E-02	SN-125	0.499E 00	RU-106	0.617E-02
7	PU-238	0.279E-01	I-129	0.102E-02	TE-129M	0.499E 00	CE-144	0.537E-02
8	I-133	0.190E-01	I-131	0.189E-03	P-32	0.499E 00	NA-22	0.415E-02
9	CS-134	0.128E-01	CE-144	0.135E-03	TE-132	0.499E 00	CO-60	0.395E-02
10	CA-45	0.127E-01	EU-152	0.982E-04	Y-90	0.499E 00	CS-134	0.291E-02
11	CE-144	0.109E-01	CA-45	0.411E-04	ZR-97	0.499E 00	BI-207	0.253E-02
12	RU-106	0.109E-01	Y-91	0.376E-04	SC-48	0.333E 00	CS-137	0.237E-02
13	CS-137	0.736E-02	CD-115M	0.357E-04	SR-89	0.333E 00	EU-152	0.188E-02
14	P-32	0.624E-02	CS-134	0.335E-04	NA-22	0.333E 00	CL-36	0.152E-02
15	I-135	0.588E-02	PM-147	0.212E-04	CD-115M	0.333E 00	TL-204	0.132E-02
16	HG-203	0.570E-02	SR-89	0.199E-04	NA-24	0.333E 00	SB-125	0.129E-02
17	LA-140	0.546E-02	SM-151	0.199E-04	CO-60	0.333E 00	ZR-93	0.117E-02
18	SN-125	0.546E-02	CS-137	0.194E-04	PU-238	0.333E 00	Y-91	0.112E-02
19	Y-90	0.546E-02	P-32	0.186E-04	PU-239	0.333E 00	TE-129M	0.105E-02
20	ZR-97	0.546E-02	TE-129M	0.174E-04	PU-240	0.333E 00	ZR-95	0.105E-02
21	SR-89	0.427E-02	HG-203	0.169E-04	Y-91	0.333E 00	IN-115	0.995E-03
22	SC-48	0.363E-02	I-135	0.158E-04	Y-93	0.333E 00	MN-54	0.957E-03
23	BA-140	0.363E-02	RU-106	0.138E-04	AG-111	0.250E 00	SR-89	0.952E-03
24	CD-115M	0.363E-02	EU-155	0.127E-04	MO-99	0.250E 00	CD-115M	0.941E-03
25	CD-115	0.363E-02	ZN-65	0.116E-04	SR-90	0.250E 00	TE-127M	0.872E-03
26	TE-129M	0.363E-02	NB-93M	0.111E-04	CD-115	0.250E 00	PU-241	0.872E-03
27	TE-132	0.363E-02	ZR-93	0.106E-04	CE-143	0.250E 00	BA-140	0.787E-03
28	Y-91	0.363E-02	SN-125	0.105E-04	CS-134	0.250E 00	FE-59	0.670E-03
29	Y-93	0.363E-02	Y-90	0.105E-04	TE-131M	0.250E 00	ZN-65	0.585E-03
30	NA-22	0.314E-02	ZR-97	0.105E-04	PB-204M	0.250E 00	TC-99	0.548E-03
31	AG-111	0.272E-02	TE-127M	0.103E-04	CS-137	0.250E 00	RB-87	0.526E-03
32	CE-143	0.272E-02	I-133	0.102E-04	PM-149	0.250E 00	I-129	0.479E-03
33	PB-204M	0.272E-02	BA-140	0.101E-04	I-133	0.250E 00	EU-155	0.465E-03
34	PM-149	0.272E-02	ZR-95	0.953E-05	AU-198	0.200E 00	P-32	0.429E-03
35	I-132	0.255E-02	LA-140	0.841E-05	SR-91	0.200E 00	SN-125	0.412E-03
36	S-35	0.222E-02	NA-22	0.824E-05	TE-127M	0.200E 00	RU-103	0.402E-03
37	AU-198	0.218E-02	BI-207	0.735E-05	PR-143	0.200E 00	CS-135	0.386E-03
38	CO-60	0.218E-02	FE-59	0.706E-05	FE-59	0.200E 00	Y-90	0.380E-03
39	PR-143	0.218E-02	SC-48	0.700E-05	BI-207	0.167E 00	ZR-97	0.380E-03
40	TE-127M	0.195E-02	Y-93	0.700E-05	SR-92	0.167E 00	PM-147	0.356E-03
41	BI-207	0.182E-02	I-132	0.682E-05	ND-147	0.167E 00	NB-95	0.343E-03
42	ND-147	0.182E-02	TE-132	0.600E-05	CL-36	0.167E 00	C-14	0.315E-03
43	TE-131M	0.182E-02	S-35	0.585E-05	CS-136	0.167E 00	W-185	0.312E-03
44	FE-59	0.182E-02	CD-115	0.525E-05	TL-204	0.167E 00	CA-45	0.290E-03
45	Y-92	0.182E-02	IN-115	0.475E-05	W-187	0.167E 00	K-42	0.285E-03
46	ZR-95	0.182E-02	CE-143	0.466E-05	Y-92	0.167E 00	LA-140	0.285E-03
47	SR-91	0.156E-02	AG-111	0.420E-05	I-131	0.167E 00	TE-132	0.285E-03
48	SR-92	0.156E-02	AU-198	0.420E-05	ZR-95	0.167E 00	HG-203	0.274E-03
49	W-187	0.156E-02	ND-147	0.420E-05	I-135	0.143E 00	W-181	0.273E-03
50	AS-77	0.136E-02	CO-60	0.420E-05	PD-109	0.143E 00	TE-125M	0.266E-03
51	SM-153	0.136E-02	TE-131M	0.420E-05	AS-77	0.125E 00	SM-151	0.245E-03

APPENDIX X, continued

COMPOSITE LISTINGS OF RADIONUCLIDES BASED ON DOSES TO THE CRITICAL ORGANS FROM 1 MICROCURIE INTAKES

GAMMA = 20.5 TAU = 0.0 T = 25550

	SOLUBLE				INSOLUBLE			
	INGESTION		INHALATION		INGESTION		INHALATION	
NO.	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED
52	EU-152	0.136E-02	PB-204M	0.420E-05	SM-153	0.125E 00	SC-48	0.228E-03
53	GD-159	0.136E-02	PM-149	0.420E-05	EU-152	0.125E 00	NA-24	0.228E-03
54	RU-103	0.136E-02	PR-143	0.420E-05	GD-159	0.125E 00	Y-93	0.228E-03
55	CL-36	0.135E-02	Y-92	0.420E-05	RU-103	0.125E 00	CE-141	0.221E-03
56	CS-136	0.128E-02	TE-125M	0.391E-05	IN-115	0.111E 00	NB-93M	0.215E-03
57	IN-115	0.121E-02	CL-36	0.353E-05	CE-141	0.111E 00	CS-136	0.200E-03
58	CE-141	0.121E-02	CS-136	0.335E-05	SB-125	0.100E 00	PR-143	0.191E-03
59	PD-109	0.121E-02	MN-54	0.326E-05	AU-196	0.100E 00	CD-115	0.190E-03
60	I-134	0.119E-02	I-134	0.320E-05	MN-54	0.100E 00	TE-131M	0.190E-03
61	ZN-65	0.111E-02	CS-135	0.261E-05	MN-56	0.100E 00	MO-99	0.163E-03
62	SB-125	0.109E-02	AS-77	0.210E-05	NB-95	0.100E 00	CE-143	0.163E-03
63	MN-54	0.109E-02	SB-125	0.210E-05	TE-125M	0.100E 00	I-133	0.163E-03
64	MN-56	0.109E-02	SM-153	0.210E-05	NP-239	0.100E 00	ND-147	0.151E-03
65	NB-95	0.109E-02	SR-91	0.210E-05	W-185	0.100E 00	AG-111	0.143E-03
66	NP-239	0.109E-02	SR-92	0.210E-05	HG-203	0.100E 00	AU-198	0.143E-03
67	TL-204	0.109E-02	CE-141	0.210E-05	RH-105	0.100E 00	PB-204M	0.143E-03
68	W-185	0.109E-02	NB-95	0.210E-05	RU-105	0.100E 00	PM-149	0.143E-03
69	RH-105	0.109E-02	PD-109	0.210E-05	C-14	0.499E-01	S-35	0.138E-03
70	RU-105	0.109E-02	TL-204	0.210E-05	CA-45	0.499E-01	SR-91	0.127E-03
71	CS-135	0.105E-02	W-187	0.210E-05	TC-99	0.499E-01	I-135	0.114E-03
72	TE-125M	0.745E-03	GD-159	0.210E-05	TE-127	0.499E-01	AS-77	0.114E-03
73	RB-87	0.723E-03	RU-103	0.210E-05	CS-135	0.499E-01	SM-153	0.114E-03
74	MO-99	0.550E-03	RB-87	0.189E-05	PB-210	0.499E-01	SR-92	0.114E-03
75	AU-196	0.546E-03	MO-99	0.161E-05	TL-201	0.499E-01	PD-109	0.114E-03
76	NA-24	0.546E-03	MN-56	0.140E-05	CU-64	0.499E-01	W-187	0.114E-03
77	PM-147	0.546E-03	NP-239	0.140E-05	PM-147	0.499E-01	GD-159	0.114E-03
78	EU-155	0.546E-03	W-185	0.140E-05	EU-155	0.499E-01	Y-92	0.114E-03
79	PU-241	0.499E-03	RH-105	0.140E-05	RB-87	0.499E-01	I-131	0.114E-03
80	K-42	0.363E-03	RU-105	0.140E-05	I-129	0.499E-01	MN-56	0.569E-04
81	TC-99	0.363E-03	FE-55	0.125E-05	ZN-65	0.499E-01	NP-239	0.569E-04
82	ND-149	0.363E-03	AU-196	0.105E-05	I-132	0.499E-01	H-3	0.569E-04
83	TE-127	0.363E-03	NA-24	0.105E-05	S-35	0.333E-01	RH-105	0.569E-04
84	TL-201	0.363E-03	ND-149	0.700E-06	ND-149	0.333E-01	RU-105	0.569E-04
85	CU-64	0.363E-03	TE-127	0.700E-06	W-181	0.333E-01	AU-196	0.548E-04
86	IN-115M	0.272E-03	K-42	0.600E-06	IN-115M	0.250E-01	TE-127	0.380E-04
87	SM-151	0.272E-03	TC-99	0.600E-06	SM-151	0.250E-01	TL-201	0.380E-04
88	NB-93M	0.272E-03	TL-201	0.600E-06	NB-93M	0.250E-01	I-132	0.380E-04
89	PB-203	0.272E-03	CU-64	0.600E-06	PB-203	0.250E-01	FE-55	0.343E-04
90	W-181	0.272E-03	IN-115M	0.525E-06	I-134	0.167E-01	BE-7	0.289E-04
91	TE-129	0.136E-03	W-181	0.525E-06	TE-129	0.125E-01	CU-64	0.285E-04
92	ZR-93	0.136E-03	PB-203	0.466E-06	ZR-93	0.125E-01	ND-149	0.228E-04
93	NB-97	0.121E-03	C-14	0.253E-06	NB-97	0.111E-01	IN-115M	0.190E-04
94	FE-55	0.119E-03	BE-7	0.224E-06	H-3	0.100E-01	PB-203	0.190E-04
95	C-14	0.963E-04	NB-97	0.210E-06	PU-241	0.100E-01	CR-51	0.154E-04
96	BE-7	0.546E-04	TE-129	0.210E-06	BE-7	0.499E-02	TE-129	0.114E-04
97	CR-51	0.546E-04	CR-51	0.105E-06	CR-51	0.499E-02	I-134	0.114E-04
98	Y-91M	0.363E-04	H-3	0.747E-07	FE-55	0.499E-02	NB-97	0.569E-05
99	H-3	0.213E-04	Y-91M	0.525E-07	TC-99M	0.333E-02	TC-99M	0.228E-05
100	TC-99M	0.182E-04	TC-99M	0.420E-07	Y-91M	0.333E-02	Y-91M	0.190E-05
101	RH-103M	0.109E-04	RH-103M	0.140E-07	RH-103M	0.100E-02	RH-103M	0.569E-06

APPENDIX X, continued

COMPOSITE LISTINGS OF RADIONUCLIDES BASED ON DOSES TO THE CRITICAL ORGANS FROM 1 MICROCURIE INTAKES
GAMMA = 20.5 TAU = 60.0 T = 365

	SOLUBLE				INSOLUBLE			
	INGESTION		INHALATION		INGESTION		INHALATION	
NO.	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED
1	I-129	0.100E 01	PU-238	0.100E 01	RU-106	0.100E 01	PU-238	0.100E 01
2	PB-210	0.821E 00	PU-239	0.968E 00	CE-144	0.971E 00	PU-239	0.934E 00
3	SR-90	0.129E 00	PU-240	0.968E 00	PU-239	0.373E 00	PU-240	0.934E 00
4	CS-134	0.373E-01	PB-210	0.221E 00	PU-240	0.373E 00	PB-210	0.250E 00
5	RU-106	0.305E-01	I-129	0.514E-01	PU-238	0.372E 00	SR-90	0.111E-01
6	CE-144	0.296E-01	PU-241	0.486E-01	CO-60	0.365E 00	RU-106	0.102E-01
7	CA-45	0.243E-01	SR-90	0.116E-01	NA-22	0.357E 00	CE-144	0.877E-02
8	CS-137	0.224E-01	CE-144	0.457E-02	SR-90	0.279E 00	NA-22	0.714E-02
9	NA-22	0.942E-02	CS-134	0.188E-02	CS-137	0.279E 00	CO-60	0.686E-02
10	HG-203	0.721E-02	CA-45	0.152E-02	CS-134	0.266E 00	CS-134	0.500E-02
11	CO-60	0.669E-02	EU-152	0.118E-02	CL-36	0.187E 00	BI-207	0.439E-02
12	SR-89	0.584E-02	CS-137	0.113E-02	BI-207	0.184E 00	CS-137	0.412E-02
13	BI-207	0.563E-02	Y-91	0.110E-02	Y-91	0.182E 00	EU-152	0.327E-02
14	Y-91	0.558E-02	CD-115M	0.816E-03	TL-204	0.180E 00	CL-36	0.265E-02
15	CD-115M	0.433E-02	RU-106	0.752E-03	SR-89	0.164E 00	TL-204	0.227E-02
16	EU-152	0.423E-02	SR-89	0.525E-03	TE-129M	0.159E 00	SB-125	0.220E-02
17	CL-36	0.421E-02	NA-22	0.475E-03	TE-127M	0.151E 00	ZR-93	0.204E-02
18	S-35	0.415E-02	BI-207	0.436E-03	CD-115M	0.142E 00	IN-115	0.173E-02
19	TE-127M	0.413E-02	PM-147	0.436E-03	EU-152	0.139E 00	MN-54	0.157E-02
20	IN-115	0.379E-02	ZN-65	0.433E-03	IN-115	0.124E 00	TE-127M	0.115E-02
21	TL-204	0.329E-02	TE-127M	0.415E-03	SB-125	0.107E 00	Y-91	0.109E-02
22	SB-125	0.326E-02	HG-203	0.411E-03	MN-54	0.977E-01	ZR-95	0.108E-02
23	TE-129M	0.323E-02	EU-155	0.314E-03	ZR-95	0.966E-01	TC-99	0.957E-03
24	CS-135	0.307E-02	TE-129M	0.298E-03	FE-59	0.891E-01	ZN-65	0.942E-03
25	MN-54	0.297E-02	ZR-95	0.295E-03	W-185	0.638E-01	RB-87	0.916E-03
26	ZR-95	0.295E-02	IN-115	0.282E-03	C-14	0.560E-01	PU-241	0.904E-03
27	FE-59	0.226E-02	CO-60	0.248E-03	TC-99	0.560E-01	I-129	0.834E-03
28	RB-87	0.225E-02	CL-36	0.213E-03	CS-135	0.560E-01	SR-89	0.827E-03
29	ZN-65	0.213E-02	S-35	0.211E-03	RB-87	0.560E-01	EU-155	0.793E-03
30	W-185	0.195E-02	SM-151	0.193E-03	I-129	0.560E-01	CD-115M	0.709E-03
31	PU-238	0.178E-02	NB-93M	0.182E-03	PB-210	0.556E-01	CS-135	0.672E-03
32	PU-239	0.173E-02	MN-54	0.171E-03	TE-125M	0.547E-01	PM-147	0.614E-03
33	PU-240	0.173E-02	FE-59	0.170E-03	PM-147	0.535E-01	TE-129M	0.589E-03
34	PM-147	0.163E-02	CS-135	0.148E-03	EU-155	0.524E-01	C-14	0.550E-03
35	EU-155	0.159E-02	ZR-93	0.143E-03	RU-103	0.507E-01	FE-59	0.528E-03
36	RU-103	0.155E-02	TL-204	0.122E-03	ZN-65	0.472E-01	CA-45	0.435E-03
37	I-131	0.147E-02	SB-125	0.121E-03	HG-203	0.452E-01	SM-151	0.426E-03
38	TC-99	0.114E-02	TE-125M	0.115E-03	CA-45	0.434E-01	W-181	0.396E-03
39	TE-125M	0.114E-02	RB-87	0.114E-03	NB-95	0.341E-01	NB-93M	0.373E-03
40	P-32	0.106E-02	I-131	0.652E-04	CE-141	0.339E-01	W-185	0.351E-03
41	NB-95	0.104E-02	P-32	0.613E-04	P-32	0.306E-01	RU-103	0.289E-03
42	CE-141	0.104E-02	W-185	0.482E-04	SM-151	0.279E-01	TE-125M	0.257E-03
43	SM-151	0.853E-03	RU-103	0.457E-04	NB-93M	0.277E-01	HG-203	0.219E-03
44	NB-93M	0.842E-03	NB-95	0.387E-04	W-181	0.277E-01	NB-95	0.207E-03
45	W-181	0.632E-03	TC-99	0.362E-04	S-35	0.232E-01	S-35	0.168E-03
46	BA-140	0.442E-03	FE-55	0.349E-04	BA-140	0.217E-01	CE-141	0.120E-03
47	ZR-93	0.427E-03	CE-141	0.345E-04	ZR-93	0.140E-01	LA-140	0.101E-03
48	PR-143	0.328E-03	W-181	0.236E-04	H-3	0.111E-01	H-3	0.989E-04
49	C-14	0.302E-03	BA-140	0.235E-04	PU-241	0.111E-01	BA-140	0.608E-04
50	SN-125	0.215E-03	C-14	0.152E-04	PR-143	0.107E-01	FE-55	0.591E-04
51	FE-55	0.173E-03	PR-143	0.122E-04	CS-136	0.759E-02	P-32	0.465E-04

APPENDIX X, continued

COMPOSITE LISTINGS OF RADIONUCLIDES BASED ON DOSES TO THE CRITICAL ORGANS FROM 1 MICROCURIE INTAKES

GAMMA = 20.5 TAU = 60.0 T = 365

	SOLUBLE				INSOLUBLE			
	INGESTION		INHALATION		INGESTION		INHALATION	
NO.	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED
52	CS-136	0.163E-03	CS-136	0.823E-05	SN-125	0.701E-02	BE-7	0.264E-04
53	ND-147	0.144E-03	SN-125	0.794E-05	FE-55	0.539E-02	PR-143	0.182E-04
54	PU-241	0.863E-04	ND-147	0.638E-05	ND-147	0.471E-02	CS-136	0.161E-04
55	BE-7	0.784E-04	BE-7	0.621E-05	BE-7	0.257E-02	SN-125	0.103E-04
56	H-3	0.663E-04	H-3	0.447E-05	CR-51	0.125E-02	ND-147	0.755E-05
57	CR-51	0.383E-04	CR-51	0.142E-05	AG-111	0.109E-02	CR-51	0.684E-05
58	AG-111	0.334E-04	AG-111	0.989E-06	I-131	0.106E-02	I-131	0.129E-05
59	AU-196	0.102E-05	AU-196	0.376E-07	AU-196	0.667E-04	AG-111	0.111E-05
60	TE-132	0.259E-07	TE-132	0.823E-09	TE-132	0.128E-05	AU-196	0.647E-07
61	Y-90	0.312E-08	Y-90	0.116E-09	Y-90	0.102E-06	TE-132	0.129E-08
62	AU-198	0.140E-08	AU-198	0.518E-10	MO-99	0.943E-07	Y-90	0.137E-09
63	TL-201	0.109E-08	TL-201	0.346E-10	TL-201	0.536E-07	MO-99	0.109E-09
64	MO-99	0.579E-09	MO-99	0.326E-10	AU-198	0.459E-07	TL-201	0.720E-10
65	CD-115	0.705E-10	CD-115	0.196E-11	NP-239	0.199E-08	AU-198	0.579E-10
66	NP-239	0.605E-10	PM-149	0.157E-11	CD-115	0.174E-08	CD-115	0.233E-11
67	PM-149	0.526E-10	NP-239	0.150E-11	PM-149	0.174E-08	NP-239	0.200E-11
68	PB-203	0.407E-11	PB-203	0.134E-12	PB-203	0.133E-09	PM-149	0.175E-11
69	SM-153	0.262E-11	SM-153	0.773E-13	SM-153	0.856E-10	PB-203	0.179E-12
70	SC-48	0.154E-11	SC-48	0.571E-13	SC-48	0.506E-10	SM-153	0.138E-12
71	LA-140	0.305E-12	LA-140	0.904E-14	LA-140	0.100E-10	SC-48	0.613E-13
72	AS-77	0.305E-13	AS-77	0.901E-15	AS-77	0.100E-11	AS-77	0.161E-14
73	RH-105	0.450E-14	RH-105	0.111E-15	RH-105	0.148E-12	RH-105	0.149E-15
74	CE-143	0.226E-15	CE-143	0.745E-17	CE-143	0.741E-14	CE-143	0.854E-17
75	TE-131M	0.204E-16	TE-131M	0.904E-18	TE-131M	0.100E-14	TE-131M	0.135E-17
76	W-187	0.427E-20	W-187	0.111E-21	W-187	0.163E-18	W-187	0.198E-21
77	I-133	0.104E-21	I-133	0.535E-23	I-133	0.490E-21	I-133	0.565E-24
78	GD-159	0.357E-26	GD-159	0.106E-27	GD-159	0.117E-24	GD-159	0.189E-27
79	ZR-97	0.626E-27	ZR-97	0.233E-28	ZR-97	0.206E-25	ZR-97	0.277E-28
80	NA-24	0.371E-31	NA-24	0.137E-32	NA-24	0.810E-29	NA-24	0.981E-32
81	PD-109	0.789E-34	PD-109	0.264E-35	PD-109	0.334E-32	PD-109	0.472E-35
82	CU-64	0.963E-37	CU-64	0.307E-38	K-42	0.105E-34	K-42	0.105E-37
83	K-42	0.214E-37	K-42	0.677E-39	CU-64	0.475E-35	CU-64	0.479E-38
84	Y-93	0.115E-44	Y-93	0.426E-46	Y-93	0.378E-43	Y-93	0.457E-46
85	SR-91	0.349E-47	SR-91	0.908E-49	SR-91	0.160E-45	SR-91	0.179E-48
86	TE-127	0.568E-49	TE-127	0.210E-50	TE-127	0.279E-47	TE-127	0.376E-50
87	I-135	0.589E-66	I-135	0.306E-67	I-135	0.514E-65	I-135	0.727E-68
88	IN-115M	0.0	IN-115M	0.0	IN-115M	0.0	IN-115M	0.0
89	MN-56	0.0	MN-56	0.0	MN-56	0.0	MN-56	0.0
90	SR-92	0.0	SR-92	0.0	SR-92	0.0	SR-92	0.0
91	TC-99M	0.0	TC-99M	0.0	TC-99M	0.0	TC-99M	0.0
92	NB-97	0.0	NB-97	0.0	NB-97	0.0	NB-97	0.0
93	ND-149	0.0	ND-149	0.0	ND-149	0.0	ND-149	0.0
94	TE-129	0.0	TE-129	0.0	TE-129	0.0	TE-129	0.0
95	PB-204M	0.0	PB-204M	0.0	PB-204M	0.0	PB-204M	0.0
96	Y-91M	0.0	Y-91M	0.0	Y-91M	0.0	Y-91M	0.0
97	Y-92	0.0	Y-92	0.0	Y-92	0.0	Y-92	0.0
98	RH-103M	0.0	RH-103M	0.0	RH-103M	0.0	RH-103M	0.0
99	I-132	0.0	I-132	0.0	I-132	0.0	I-132	0.0
100	RU-105	0.0	RU-105	0.0	RU-105	0.0	RU-105	0.0
101	I-134	0.0	I-134	0.0	I-134	0.0	I-134	0.0

APPENDIX X, continued

COMPOSITE LISTINGS OF RADIONUCLIDES BASED ON DOSES TO THE CRITICAL ORGANS FROM 1 MICROCURIE INTAKES

GAMMA = 20.5 TAU = 60.0 T = 25550

	SOLUBLE				INSOLUBLE			
	INGESTION		INHALATION		INGESTION		INHALATION	
NO.	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED
1	SR-90	0.100E 01	PU-239	0.100E 01	RU-106	0.100E 01	PU-238	0.100E 01
2	PB-210	0.655E 00	PU-240	0.100E 01	CE-144	0.971E 00	PU-239	0.941E 00
3	I-129	0.382E 00	PU-238	0.812E 00	PU-239	0.373E 00	PU-240	0.941E 00
4	PU-239	0.345E-01	PU-241	0.144E-01	PU-240	0.373E 00	PB-210	0.143E 00
5	PU-240	0.345E-01	PB-210	0.912E-02	PU-238	0.372E 00	SR-90	0.633E-02
6	PU-238	0.280E-01	SR-90	0.465E-02	CO-60	0.365E 00	RU-106	0.548E-02
7	CS-134	0.122E-01	I-129	0.103E-02	NA-22	0.357E 00	CE-144	0.465E-02
8	CA-45	0.988E-02	CE-144	0.117E-03	SR-90	0.279E 00	NA-22	0.397E-02
9	RU-106	0.978E-02	EU-152	0.971E-04	CS-137	0.279E 00	CO-60	0.387E-02
10	CE-144	0.949E-02	CA-45	0.319E-04	CS-134	0.266E 00	CS-134	0.277E-02
11	CS-137	0.738E-02	CS-134	0.319E-04	CL-36	0.187E 00	BI-207	0.249E-02
12	NA-22	0.302E-02	PM-147	0.202E-04	BI-207	0.184E 00	CS-137	0.236E-02
13	HG-203	0.231E-02	SM-151	0.199E-04	Y-91	0.182E 00	EU-152	0.186E-02
14	CO-60	0.215E-02	CS-137	0.193E-04	TL-204	0.180E 00	CL-36	0.152E-02
15	SR-89	0.189E-02	Y-91	0.184E-04	SR-89	0.164E 00	TL-204	0.127E-02
16	BI-207	0.181E-02	CD-115M	0.136E-04	TE-129M	0.159E 00	SB-125	0.122E-02
17	Y-91	0.179E-02	RU-106	0.125E-04	TE-127M	0.151E 00	ZR-93	0.117E-02
18	CD-115M	0.139E-02	EU-155	0.119E-04	CD-115M	0.142E 00	IN-115	0.995E-03
19	S-35	0.138E-02	NB-93M	0.110E-04	EU-152	0.139E 00	PU-241	0.867E-03
20	EU-152	0.136E-02	ZR-93	0.106E-04	IN-115	0.124E 00	MN-54	0.835E-03
21	CL-36	0.135E-02	ZN-65	0.982E-05	SB-125	0.107E 00	TE-127M	0.585E-03
22	TE-127M	0.132E-02	SR-89	0.876E-05	MN-54	0.977E-01	TC-99	0.548E-03
23	IN-115	0.122E-02	NA-22	0.788E-05	ZR-95	0.966E-01	Y-91	0.548E-03
24	TL-204	0.106E-02	BI-207	0.724E-05	FE-59	0.891E-01	ZR-95	0.543E-03
25	CS-135	0.105E-02	TE-127M	0.688E-05	W-185	0.638E-01	RB-87	0.526E-03
26	SB-125	0.105E-02	HG-203	0.682E-05	C-14	0.560E-01	ZN-65	0.496E-03
27	TE-129M	0.104E-02	TE-129M	0.494E-05	TC-99	0.560E-01	I-129	0.479E-03
28	MN-54	0.954E-03	ZR-95	0.494E-05	CS-135	0.560E-01	EU-155	0.435E-03
29	ZR-95	0.948E-03	IN-115	0.475E-05	RB-87	0.560E-01	SR-89	0.418E-03
30	ZN-65	0.939E-03	CO-60	0.411E-05	I-129	0.560E-01	CS-135	0.386E-03
31	FE-59	0.726E-03	S-35	0.364E-05	PB-210	0.556E-01	CD-115M	0.357E-03
32	RB-87	0.726E-03	CL-36	0.353E-05	TE-125M	0.547E-01	PM-147	0.341E-03
33	W-185	0.625E-03	MN-54	0.284E-05	PM-147	0.535E-01	C-14	0.315E-03
34	PM-147	0.524E-03	FE-59	0.282E-05	EU-155	0.524E-01	TE-129M	0.297E-03
35	EU-155	0.512E-03	CS-135	0.261E-05	RU-103	0.507E-01	FE-59	0.266E-03
36	PU-241	0.497E-03	TL-204	0.202E-05	ZN-65	0.472E-01	SM-151	0.244E-03
37	RU-103	0.497E-03	SB-125	0.200E-05	HG-203	0.452E-01	CA-45	0.225E-03
38	I-131	0.405E-03	TE-125M	0.191E-05	CA-45	0.434E-01	NB-93M	0.213E-03
39	TC-99	0.365E-03	RB-87	0.189E-05	NB-95	0.341E-01	W-181	0.203E-03
40	TE-125M	0.365E-03	FE-55	0.121E-05	CE-141	0.339E-01	W-185	0.178E-03
41	P-32	0.341E-03	I-131	0.108E-05	P-32	0.306E-01	RU-103	0.146E-03
42	NB-95	0.334E-03	P-32	0.102E-05	SM-151	0.279E-01	TE-125M	0.130E-03
43	CE-141	0.333E-03	W-185	0.800E-06	NB-93M	0.277E-01	HG-203	0.111E-03
44	SM-151	0.274E-03	RU-103	0.759E-06	W-181	0.277E-01	NB-95	0.104E-03
45	NB-93M	0.270E-03	NB-95	0.641E-06	S-35	0.232E-01	S-35	0.851E-04
46	W-181	0.203E-03	TC-99	0.600E-06	BA-140	0.217E-01	CE-141	0.606E-04
47	BA-140	0.142E-03	CE-141	0.573E-06	ZR-93	0.140E-01	H-3	0.564E-04
48	ZR-93	0.137E-03	W-181	0.391E-06	H-3	0.111E-01	FE-55	0.330E-04
49	FE-55	0.116E-03	BA-140	0.391E-06	PU-241	0.111E-01	BA-140	0.306E-04
50	PR-143	0.105E-03	C-14	0.253E-06	PR-143	0.107E-01	P-32	0.235E-04
51	C-14	0.968E-04	PR-143	0.202E-06	CS-136	0.759E-02	BE-7	0.133E-04

APPENDIX X, continued

COMPOSITE LISTINGS OF RADIONUCLIDES BASED ON DOSES TO THE CRITICAL ORGANS FROM 1 MICROCURIE INTAKES

GAMMA = 20.5 TAU = 60.0 T = 25550

	SOLUBLE				INSOLUBLE			
	INGESTION		INHALATION		INGESTION		INHALATION	
NO.	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED	NUCLIDE	NORMALIZED
52	SN-125	0.689E-04	CS-136	0.136E-06	SN-125	0.701E-02	PR-143	0.920E-05
53	CS-136	0.524E-04	SN-125	0.132E-06	FE-55	0.539E-02	CS-136	0.814E-05
54	ND-147	0.461E-04	ND-147	0.106E-06	ND-147	0.471E-02	SN-125	0.517E-05
55	BE-7	0.252E-04	BE-7	0.103E-06	BE-7	0.257E-02	ND-147	0.381E-05
56	H-3	0.213E-04	H-3	0.741E-07	CR-51	0.125E-02	CR-51	0.345E-05
57	CR-51	0.123E-04	CR-51	0.235E-07	AG-111	0.109E-02	I-131	0.649E-06
58	AG-111	0.107E-04	AG-111	0.164E-07	I-131	0.106E-02	AG-111	0.559E-06
59	AU-196	0.326E-06	AU-196	0.624E-09	AU-196	0.667E-04	AU-196	0.326E-07
60	TE-132	0.831E-08	TE-132	0.136E-10	TE-132	0.128E-05	TE-132	0.649E-09
61	Y-90	0.100E-08	Y-90	0.192E-11	Y-90	0.102E-06	Y-90	0.691E-10
62	AU-198	0.449E-09	AU-198	0.859E-12	MO-99	0.943E-07	MO-99	0.548E-10
63	TL-201	0.350E-09	TL-201	0.574E-12	TL-201	0.536E-07	TL-201	0.363E-10
64	MO-99	0.186E-09	MO-99	0.541E-12	AU-198	0.459E-07	AU-198	0.292E-10
65	CD-115	0.226E-10	CD-115	0.325E-13	NP-239	0.199E-08	CD-115	0.118E-11
66	NP-239	0.194E-10	PM-149	0.260E-13	PM-149	0.184E-08	NP-239	0.101E-11
67	PM-149	0.169E-10	NP-239	0.249E-13	CD-115	0.174E-08	PM-149	0.883E-12
68	PB-203	0.131E-11	PB-203	0.222E-14	PB-203	0.133E-09	PB-203	0.904E-13
69	SM-153	0.840E-12	SM-153	0.128E-14	SM-153	0.856E-10	SM-153	0.697E-13
70	SC-48	0.495E-12	SC-48	0.947E-15	SC-48	0.506E-10	SC-48	0.309E-13
71	LA-140	0.978E-13	LA-140	0.150E-15	LA-140	0.100E-10	LA-140	0.508E-14
72	AS-77	0.978E-14	AS-77	0.149E-16	AS-77	0.100E-11	AS-77	0.814E-15
73	RH-105	0.144E-14	RH-105	0.185E-17	RH-105	0.148E-12	RH-105	0.750E-16
74	CE-143	0.725E-16	CE-143	0.124E-18	CE-143	0.741E-14	CE-143	0.431E-17
75	TE-131M	0.654E-17	TE-131M	0.150E-19	TE-131M	0.100E-14	TE-131M	0.681E-18
76	W-187	0.137E-20	W-187	0.184E-23	W-187	0.163E-18	W-187	0.100E-21
77	I-133	0.334E-22	I-133	0.894E-25	I-133	0.490E-21	I-133	0.285E-24
78	GD-159	0.115E-26	GD-159	0.176E-29	GD-159	0.117E-24	GD-159	0.952E-28
79	ZR-97	0.201E-27	ZR-97	0.387E-30	ZR-97	0.206E-25	ZR-97	0.140E-28
80	NA-24	0.119E-31	NA-24	0.228E-34	NA-24	0.810E-29	NA-24	0.495E-32
81	PD-109	0.253E-34	PD-109	0.438E-37	PD-109	0.334E-32	PD-109	0.238E-35
82	CU-64	0.309E-37	CU-64	0.509E-40	K-42	0.105E-34	K-42	0.532E-38
83	K-42	0.686E-38	K-42	0.112E-40	CU-64	0.475E-35	CU-64	0.241E-38
84	Y-93	0.370E-45	Y-93	0.706E-48	Y-93	0.378E-43	Y-93	0.230E-46
85	SR-91	0.112E-47	SR-91	0.151E-50	SR-91	0.160E-45	SR-91	0.904E-49
86	TE-127	0.182E-49	TE-127	0.349E-52	TE-127	0.279E-47	TE-127	0.189E-50
87	I-135	0.189E-66	I-135	0.508E-68	I-135	0.514E-65	I-135	0.366E-68
88	IN-115M	0.0	IN-115M	0.0	IN-115M	0.0	IN-115M	0.0
89	MN-56	0.0	MN-56	0.0	MN-56	0.0	MN-56	0.0
90	SR-92	0.0	SR-92	0.0	SR-92	0.0	SR-92	0.0
91	TC-99M	0.0	TC-99M	0.0	TC-99M	0.0	TC-99M	0.0
92	NB-97	0.0	NB-97	0.0	NB-97	0.0	NB-97	0.0
93	ND-149	0.0	ND-149	0.0	ND-149	0.0	ND-149	0.0
94	TE-129	0.0	TE-129	0.0	TE-129	0.0	TE-129	0.0
95	PB-204M	0.0	PB-204M	0.0	PB-204M	0.0	PB-204M	0.0
96	Y-91M	0.0	Y-91M	0.0	Y-91M	0.0	Y-91M	0.0
97	Y-92	0.0	Y-92	0.0	Y-92	0.0	Y-92	0.0
98	RH-103M	0.0	RH-103M	0.0	RH-103M	0.0	RH-103M	0.0
99	I-132	0.0	I-132	0.0	I-132	0.0	I-132	0.0
100	RU-105	0.0	RU-105	0.0	RU-105	0.0	RU-105	0.0
101	I-134	0.0	I-134	0.0	I-134	0.0	I-134	0.0

APPENDIX XI

COMPUTER PROGRAMS

All computer programs were written in FORTRAN 360 for an IBM 360 Model 75. FORTRAN 360 is a language that has all of the features of FORTRAN 63 and FORTRAN IV and is easily converted into either.

Program EXRAD — External Dose Calculations

The input data for EXRAD are arranged in groups. The following is a list of the group numbers and the information contained on each card:[a]

Group 1: Card 1 contains the number of time periods (in weeks). Card 2, the time periods.

Group 2: Card 1 contains the list number of the radionuclides with forbidden spectra. Card 2 has a one for each such radionuclide. Card 3 contains $\overline{E}/\overline{E}*$ for the radionuclides on card 1.

Group 3: A deck of cards listing the radionuclides and a deck listing the decay constants, followed by a card with coefficients for the four submersion equations.

Group 4: A deck of cards listing the number of beta particles for each radionuclide.

---

[a]See program for arrangement of data on cards, and Chapter 3.0 for more complete definition of terms and corresponding units.

APPENDIX XI, continued

Group 5: Each radionuclide has a subgroup. The first card of the subgroup contains the effective absorbed energy of each beta-particle disintegration. The second card contains the concentration in microcuries (one entry for each particle). The third card contains the fraction of time each particle is emitted per disintegration.

Group 6: Same as Group 4, except for gamma rays.

Group 7: Same as Group 5, except for gamma rays.

Group 8: Same as Group 4, with one additional card that contains the distance above ground surface for beta exposures.

Group 9: A list of the maximum beta-particle energies (one for each particle).

Group 10: Same as Group 7, with one additional card which contains the distance above ground surface for gamma exposures.

Group 11: A list of the linear energy absorption coefficients.

Group 12: This group has a subgroup for each distance in Group 11. These subgroups are the E_1 function evaluated at the distances given in Group 11.

It should be pointed out that EXRAD uses tape unit 32 for temporary storage.

APPENDIX XI, continued

```
**FTN,L,A,E.
      PROGRAM EXRAD
      COMMON/B1/NAME
      COMMON/BL2/NI
      COMMON/BL3/NT,DIS,III
      COMMON/BL4/IKI
      COMMONT,NAME1,V,NP1
      DIMENSIONXX(200)
      DIMENSIOND(10,200),F(10,200),C(200),XC(10),TD(200,10),
     1T(20)              ,V(200),NP1(200),E(10,200),Q(10,200),LAM(200)
     2,E0(10,200),SP(10),KIP(10),CC(10,200),ALPHA(10,200)
     3,D1(10,200),IP(10),SIG(10,200)
     4,XOLD(200),XNEW(200),DIS(10),E1(10,200) ,
     5SD1(10,200),SD2(10,200),SF1(10,200),SF2(10,200)
      REALLAM,NU(10,200)
      DOUBLEPRECISIONT1,NAME(200),NAME1(200)
      DN=1.
      IKI=0
      READ1,NI,NT
      DO2000IZAP=1,NI
 2000 XX(IZAP)=-1.
      READ2,(T(I),I=1,NT)
      READ909,(KIP(I),I=1,4)
      READ909,(IP(I),I=1,4)
      READ2,(SP(IJ),IJ=1,4)
  909 FORMAT(8I10)
      READ82,(NAME1(I),I=1,NI)
   82 FORMAT(10A8)
      READ2,(LAM(I),I=1,NI)
      C=3600.*24.*7.
      DO590IJ=1,NI
  590 LAM(IJ)=LAM(IJ)*C
   80 FORMAT(16I5)
    1 FORMAT(8I10)
      I110=0$I111=0$I12=0
    2 FORMAT(8E10.6)
      READ2,(XC(I),I=1,4)
      DO25I007=1,4
      IF(I007.EQ.1.OR.I007.EQ.3)170,171
  170 READ80,(NP1(K),K=1,NI)
      DO3I=1,NI
      NP=NP1(I)
      READ2,(E(N,I),N=1,NP)
      READ2,(Q(N,I),N=1,NP)
      READ2,(F(N,I),N=1,NP)
    3 CONTINUE
      IF(I007.EQ.1)260,261
  260 DO250IJ=1,NI
      NP=NP1(IJ)
      DO250IK=1,NP
      SF1(IK,IJ)=F(IK,IJ)
  250 SD1(IK,IJ)=E(IK,IJ)
      GOTO262
  261 DO251IJ=1,NI
      NP=NP1(IJ)
      DO251IK=1,NP
      SF2(IK,IJ)=F(IK,IJ)
  251 SD2(IK,IJ)=E(IK,IJ)
  262 CONTINUE
  171 DO 5 I=1,NI
      NP=NP1(I)
```

APPENDIX XI, continued

```
      DO5N=1,NP
    5 D(N,I)=XC(I007)*Q(N,I)*E(N,I)
      DO6I=1,NI
      C(I)=0.
      NP=NP1(I)
      DO7N=1,NP
    7 C(I)=C(I)+F(N,I)*D(N,I)
    6 C(I)=C(I)/24.
      DO8I=1,NI
      DO8J=1,NT
    8 TD(I,J)=C(I)*EXPF(-LAM(I)*T(J))
      DO10J=1,NT
      DO11I=1,NI
   11 V(I)=TD(I,J)
      WRITE(32)(V(I1),I1=1,NI)
      WRITE(32)(XX(IK),IK=1,NI)
   10 CONTINUE
      DO18I=1,NI
      DO18J=1,NT
   18 TD(I,J)=-C(I)/LAM(I)*(EXPF(-LAM(I)*T(J))-1.)*168.
      DO19I=1,NI
      XNEW(I)=C(I)/LAM(I)
     1*168.
   19 CONTINUE
      DO30J1=1,NT
      DO31I1=1,NI
   31 V(I1)=TD(I1,J1)
      WRITE(32)(V(I1),I1=1,NI)
      WRITE(32)(XX(IK),IK=1,NI)
   30 CONTINUE
      WRITE(32)(XNEW(I1),I1=1,NI)
      WRITE(32)(XX(IK),IK=1,NI)
   25 CONTINUE
      CALL MATCH(NT,NI,0,1,0)
      CALLMATCH(2*NT,NI,0,NT,1)
      CALLMATCH(3*NT+1,NI,1,2*NT+2,0)
      CALLMATCH(4*NT+1,NI,1,3*NT+1,1)
      REWIND32
C     EQUATIONS 1 AND 2 ARE COMPLETE
   61 READ80,(NP1(K),K=1,NI)
      READ103,(DIS(K),K=1,3)
  103 FORMAT(8F10.5)
      DO60IDIS=1,3
      IF(I110.EQ.0)189,195
  195 IF(I111.EQ.0)202,203
  202 I111=1
      DO255IJ=1,NI
      NP=NP1(IJ)
  255 READ204,(SIG(N,IJ),N=1,NP)
      DO912IK=1,NI
      NP=NP1(IK)
      DO912N=1,NP
  912 SIG(N,IK)=SIG(N,IK)*10.**(-10)
  204 FORMAT(8E10.5)
      DO205I07=1,NI
      NP=NP1(I07)
      READ204,(E1(N,I07),N=1,NP)
  205 CONTINUE
      DO253IJ=1,NI
      NP=NP1(IJ)
      DO253IK=1,NP$F(IK,IJ)=SF2(IK,IJ)
  253 E(IK,IJ)=SD2(IK,IJ)
```

APPENDIX XI, continued

```
      GOTO931
  203 DO206I07=1,NI
      NP=NP1(I07)
      READ204,(E1(N,I07),N=1,NP)
  206 CONTINUE
  931 CONTINUE
      DO208I07=1,NI
      C(I07)=0.
      NP=NP1(I07)
      DO208N=1,NP
  208 C(I07)=C(I07)+827.*DN*SIG(N,I07)*1.14 *
     1E(N,I07)*F(N,I07)*E1(N,I07)
      GOTO209
  189 IF(I12.EQ.0)210,211
  210 DO121J1=1,NI
      NP=NP1(J1)
      READ102,(E0(N,J1),N=1,NP)
  121 CONTINUE
      DO252IJ=1,NI
      NP=NP1(IJ)
      DO252IK=1,NP
      F(IK,IJ)=SF1(IK,IJ)
  252 E(IK,IJ)=SD1(IK,IJ)
      I12=1
  102 FORMAT(8E10.5)
  211 DO120J1=1,NI
      NP=NP1(J1)$RATIO=1.
      DO120K1=1,NP
      DO104I005=1,4
      IF(J1.EQ.KIP(I005).AND.K1.EQ.IP(I005))105,104
  105 RATIO=SP(I005)
      GOTO140
  104 CONTINUE
  140 IF(E0(K1,J1).LT. .036)290,291
  290 NU(K1,J1)=0.
      GOTO107
  291 NU(K1,J1)=18.6/(E0(K1,J1)-.036)**1.37*(2-RATIO)
      IF(E0(K1,J1).LT..17)107,108
  107 CC(K1,J1)=3.
      ALPHA(K1,J1)=.19
      GOTO120
  108 IF(E0(K1,J1).LT..5)109,110
  109 CC(K1,J1)=2.$ALPHA(K1,J1)=.26
      GOTO120
  110 IF(E0(K1,J1).LT.1.5)111,112
  111 CC(K1,J1)=1.5
      ALPHA(K1,J1)=.297
      GOTO120
  112 CC(K1,J1)=1.
      ALPHA(K1,J1)=.333
  120 CONTINUE
      DO160J1=1,NI
      NP=NP1(J1)
      DO160K1=1,NP
      IF(NU(K1,J1).EQ.0.)163,93
   93 IF(NU(K1,J1)*DIS(IDIS).GE.CC(K1,J1))161,162
  161 FACT=0.
      GOTO163
  162 FACT=1.+LOGF(CC(K1,J1)/(NU(K1,J1)*DIS(IDIS)))
     1-EXPF(1.-NU(K1,J1)*DIS(IDIS)/CC(K1,J1))
  163 D(K1,J1)=1.07*NU(K1,J1)*E(K1,J1)*ALPHA(K1,J1)*
     1DN*(CC(K1,J1)*FACT+EXPF(1.-NU(K1,J1)*DIS(IDIS)))
```

APPENDIX XI, continued

```
160 CONTINUE
    DO50I=1,NI
    NP=NP1(I)
    C(I)=0.
    DO50N=1,NP
 50 C(I)=C(I)+F(N,I)*D(N,I)
209 DO52I=1,NI
    DO52J=1,NT
 52 TD(I,J)=C(I)*EXPF(-LAM(I)*T(J))
    DO54J=1,NT
    DO53I=1,NI
 53 V(I)=TD(I,J)
    WRITE(32)(V(I1),I1=1,NI)
    WRITE(32)(XX(IK),IK=1,NI)
 54 CONTINUE
    DO55I=1,NI
    DO55J=1,NT
 55 TD(I,J)=-C(I)/LAM(I)*(EXPF(-LAM(I)*T(J))-1.)
   1*168.
    DO56I=1,NI
    XNEW(I)=C(I)/LAM(I)
   1*168.
 56 CONTINUE
    DO59J1=1,NT
    DO58I1=1,NI
 58 V(I1)=TD(I1,J1)
    WRITE(32)(V(I1),I1=1,NI)
    WRITE(32)(XX(IK),IK=1,NI)
 59 CONTINUE
    WRITE(32)(XNEW(I1),I1=1,NI)
    WRITE(32)(XX(IK),IK=1,NI)
 60 CONTINUE
    II1=1
    IF(I11C.EQ.0)332,333
333 CALL MATCH(NT,NI,2,1,0)
    CALLMATCH(2*NT,NI,2,NT,1)
    II1=2
    CALLMATCH(3*NT+1,NI,2,2*NT+2,0)
    CALLMATCH(4*NT+1,NI,2,3*NT+1,1)
    II1=3
    CALLMATCH(5*NT+2,NI,2,4*NT+3,0)
    CALLMATCH(6*NT+2,NI,2,5*NT+2,1)
332 I11C=1
    GOTO61
100 END
```

APPENDIX XI, continued

```
      SUBROUTINEMATCH(IUP,NI,IPRINT,ILO,KC)
      COMMON/B1/NAME
      COMMON/BL3/NT,DIS,III
      COMMON/BL4/IKI
      COMMONT,NAME1,V,NP1
      DOUBLE PRECISION INAM,JNAM
      DOUBLE PRECISION KNAM
      DOUBLEPRECISIONNAME(200),NAME1(200),N1(200),N2(200)
      DIMENSIONV(200),V1(200),NP1(200),T(20)
      DIMENSIONV2(200),DIS(10)
  911 FORMAT(10H DISTANCE=,E20.6)
  477 FORMAT(1H ,2X,3HNO.,4X,7HNUCLIDE,7X,A7,6X,7HNUCLIDE,7X,A7,6X,7HNUC
     1LIDE,7X,A7)
    6 FORMAT('    LISTING OF RADIONUCLIDES FOR SUBMERSION DOSE RATES IN W
     1ATER CONTAINING INITIALLY 1 MICROCURIE PER GRAM')
   12 FORMAT('    LISTING OF RADIONUCLIDES FOR SUBMERSION DOSE RATES IN A
     1IR CONTAINING INITIALLY 1 MICROCURIE PER GRAM')
   16 FORMAT('    LISTING OF RADIONUCLIDES FOR DOSE RATES ABOVE GROUND SU
     1RFACE CONTAMINIED INITIALLY WITH 1 MICROCURIE PER SQ CM')
  471 FORMAT('     LISTING OF RADIONUCLIDES FOR ACCUMULATED SUBMERSION DO
     1SE IN WATER CONTAINING INITIALLY 1 MICROCURIE PER GRAM')
  472 FORMAT('     LISTING OF RADIONUCLIDES FOR ACCUMULATED SUBMERSION DO
     1SES IN AIR CONTAINING INITIALLY 1 MICROCURIE PER GRAM')
  473 FORMAT('     LISTING OF RADIONUCLIDES FOR ACCUMULATED DOSES
     1ABOVE GROUND SURFACE CONTAMINATED INITIALLY WITH 1 MICROCURIE PER
     2SQ CM')
  998 FORMAT(1H1)
      K007=0
      DO1I=ILO,IUP
      REWIND32
      CALL RECF(I-1+KC)
      READ(32)(V(I1),I1=1,NI)
      IF(IPRINT.EQ.2)25,26
   25 CALLREOF(6*NT+3)
      GOTO27
   26 CALLREOF(4*NT+2)
   27 CONTINUE
      READ(32)(V1(I1),I1=1,NI)
      DO2J=1,NI
    2 V2(J)=V(J)+V1(J)
      DO3J=1,NI
    3 NAME(J)=NAME1(J)
      CALLORDER(V2,NI)
      DO50IT=1,NI
      N1(IT)=NAME(IT)
   50 NAME(IT)=NAME1(IT)
      CALLORDER(V1,NI)
      DO51IT=1,NI
      N2(IT)=NAME(IT)
   51 NAME(IT)=NAME1(IT)
      CALLORDER(V,NI)
      PRINT 998
      IKI=IKI+1
   60 FORMAT(1H ,60X,4HPAGE,I7)
      INAM=8HTIME
      JNAM=8H
      IF(IPRINT.EQ.0)4,5
    4 IF(KC.EQ.0)GO TO 474
      PRINT 471
      KNAM=8HREMS
```

APPENDIX XI, continued

```
      GOTO 7
  474 PRINT 6
      KNAM=8HREMS/HR
      GOTO 7
    5 IF(IPRINT.EQ.1)9,10
    9 IF(KC.EQ.0)GOTO 475
      PRINT 472
      KNAM=8HREMS
      GOTO 7
  475 PRINT12
      KNAM=8HREMS/HR
      GOTO 7
   10 JNAM=8HTAU   0
      IF(KC.EQ.0)GOTO 476
      PRINT 473
      KNAM=8HREMS
      PRINT911,DIS(II1)
      GOTO 7
  476 PRINT 16
      KNAM=8HREMS/HR
      PRINT911,DIS(II1)
    7 CONTINUE
      IF(ILO.EQ.1)18,19
   18 PRINT  20, INAM,T(I), JNAM
   20 FORMAT(1H ,A8,F15.0,A8)
      GOTO21
   19 K007=K007+1
      IF(K007.GT.NT)60,611
  611 PRINT 20, INAM,T(K007), JNAM
      GOTO625
   60 PRINT63
   63 FORMAT(16H TIME = INFINITY)
  625 CONTINUE
   21 CONTINUE
   57 CONTINUE
      PRINT 478
      PRINT 477,KNAM,KNAM,KNAM
  478 FORMAT(18X,9HBETA DOSE,18X,10HGAMMA DOSE,18X,10HTOTAL DOSE)
  229 FORMAT(1H ,9HDOSE RATE)
  230 FORMAT(1H ,10HTOTAL DOSE)
      KI=1
      DO54IK=1,NI
      IF(KI.GT.50)61,62
   61 KI=1
      PRINT998
      IKI=IKI+1
      GOTO64
   62 KI=KI+1
   64 CONTINUE
      PRINT 52, IK,NAME(IK),V(IK),N2(IK),V1(IK),N1(IK),V2(IK)
   52 FORMAT(1H ,I5,3X,3(A8,3X,E12.5,5X))
   54 CONTINUE
    1 CONTINUE
      END
```

APPENDIX XI, continued

```
      SUBROUTINEORDER(V,N)
      COMMON/B1/NAME
      DOUBLEPRECISIONNAME(200),I1
      DIMENSIONV(1)
      IUP=N
    3 IC=0
      IUP=IUP-1
      DO1I=1,IUP
      IF(V(I).LT.V(I+1))2,1
    2 T=V(I)
      I1=NAME(I)
      V(I)=V(I+1)$NAME(I)=NAME(I+1)
      V(I+1)=T
      NAME(I+1)=I1
      IC=1
    1 CONTINUE
      IF(IC.EQ.1)3,4
    4 END
```

```
      SUBROUTINEREOF(I)
      COMMON/BL2/NI
      DIMENSIONA(200)
      IF(I.LT.1)2,3
    3 DO1J=1,I
    4 READ(32)(A(I1),I1=1,NI)
      IF(A(1).LT.0.)1,4
    1 CONTINUE
    2 END
```

APPENDIX XI, continued

Program INRAD — Internal Dose Calculations

The input data for INRAD are arranged in groups. The following is a list of the group numbers and the information contained on each card:[b]

Group 1: Card 1 contains the number of organs, radionuclides, post-detonation intake times, age groups, output age groups, and output times.

Group 2: The names of radionuclides and their half-lives.

Group 3: Weight of organs for each age, from age 0.5 through the number of age groups.

Group 4: Card 1 contains the output values for age groups. Card 2 contains the output values for post-detonation intake times. Card 3 contains the output values for time.

Group 5: Intake of water and air for each age.

Group 6: This group has a subgroup for each organ. Card 1 contains the name of the organ, the following cards contain the effective absorbed energy, fraction of the intake that arrives in the organ from water and air, and effective half-time of each radionuclide.

Group 7: The maximum permissible concentration for each radionuclide in the soluble form for the G.I. tract.

Group 8: The maximum permissible concentration for each radionuclide in the insoluble form for the G.I. tract.

---

[b]See program for arrangement of data on cards, and Chapter 4.0 for more complete definition of terms and corresponding units.

APPENDIX XI, continued

Group 9: The effective absorbed energy and the fraction of the radionuclide that arrives in the lungs.

```
**FTN,L,A,G,E.
      PROGRAM INRAD
      DIMENSION S1A(112,48), S1W(112,48), N9(112)
      COMMON NAME,NNUC
      DOUBLE PRECISION NAME(192), NAME1(192), NAME2(192), ORGNAM(8)
      DIMENSION TL(192)
      INTEGER TIMOUT
      DIMENSION SGAMW(128), SGAMA(128), TDOSEA(112), V1(112),
     1 V2(112), TDOSEW(112), WSMA(32,125), GAMOUT(16), TAUOUT(16),
     2 TIMOUT(16), EPS(112), EW(112), FA(112), TE(112), MPCWS(112),
     3 MPCAS(112), TR(112), EPS1(112), FW1(112), FA1(112), TE1(112),
     4 TSTOPA(112), TSTOPW(112)
      REAL MPCWS, MPCAS
      READ(50,100) NORG, NNUC, NTIM, NTAU, NGAMA, NOTIM, NOTAU, NOGAM
  100 FORMAT(16I5)
 2500 FORMAT('1',//,' LISTING OF RADIONUCLIDES FOR INDIVIDUAL ORGANS (DO
     1SE/UNIT INTAKE)')
      DO 10 I=1,NNUC
      READ(50,101) NAME(I), TR(I)
   10 TR(I)=.693/TR(I)
  101 FORMAT(A8,E12.0)
      DO 20 I=1,NORG
   20 READ(50,102) (WSMA(I,J),J=1,NGAMA)
  102 FORMAT(2X,13F6.0)
      READ(50,103) (GAMOUT(I),I=1,NOGAM)
      READ(50,103) (TAUOUT(I),I=1,NOTAU)
      READ(50,100) (TIMOUT(I),I=1,NOTIM)
  103 FORMAT(8E10.0)
      JTIM=TIMOUT(NTIM)
      M=0
      DO 30 I=1,NGAMA
   30 READ(50,104) SGAMW(I), SGAMA(I)
  104 FORMAT(10X,F10.0,F10.0)
      K=NGAMA+1
      L=JTIM+K
      DO 35 J=1,NORG
      DO 35 I=K,L
   35 WSMA(J,I)=WSMA(J,NGAMA)
      READ(50,106) (ORGNAM(I),I=1,2)
      DO 40 I=1,NNUC
      READ(50,105) EPS1(I), FW1(I), FA1(I), TE1(I)
  105 FORMAT(2X,4E8.0)
      EPS(I)=EPS1(I)
      FW(I)=FW1(I)
      FA(I)=FA1(I)
      TE(I)=TE1(I)
   40 TL(I)=.693/TE(I)
  106 FORMAT(10X,2A8)
      IOR=1
      GO TO 60
   72 IOR=IOR+1
      M=0
      IF(IOR.EQ.4) IOR=5
   70 READ(50,106) (ORGNAM(I),I=1,2)
      DO 50 I=1,NNUC
      READ(50,107) EPS(I), FW(I), FA(I)  TE(I), NEX
  107 FORMAT(2X,4E8.0,34X,I2)
      IF(NEX.EQ.9) 55, 50
   55 EPS(I)=EPS1(I)
      FW(I)=FW1(I)
      FA(I)=FA1(I)
```

APPENDIX XI, continued

```
      TE(I)=TE1(I)
      M=M+1
      N9(M)=I
   50 TL(I)=.693/TE(I)
   60 CONTINUE
      RATA=SGAMA(21)/WSMA(IOR,21)
      RATW=SGAMW(21)/WSMA(IOR,21)
      SMM=WSMA(IOR,21)
      DO 800 IGAM=1,NOGAM
      IRUN=GAMOUT(IGAM)+.6
      DO 800 ITAU=1,NOTAU
      IO=1
      TAU=TAUOUT(ITAU)
      DO 400 I=1,NNUC
      TDOSEA(I)=0.0
      TSTORA(I)=0.0
      TDOSEW(I)=0.0
  400 TSTORW(I)=0.0
      DO 800 IT=1,JTIM
      HA=SGAMA(IRUN)/WSMA(IOR,IRUN+IT-1)/RATA
      HW=SGAMW(IRUN)/WSMA(IOR,IRUN+IT-1)/RATW
      T=IT*365.0
      DO 810 I=1,NNUC
      CO=EXP(-TR(I)*TAU)*51.0*EPS(I)*TE(I)/(SMM*.693)*
     1 (1.0-EXP(-TL(I)*T))
      DA=CO*FA(I)
      DW=CO*FW(I)
      TDOSEA(I)=TDOSEA(I) + HA*(DA-TSTORA(I))
      TSTORA(I)=DA
      TDOSEW(I)=TDOSEW(I) + HW*(DW-TSTORW(I))
  810 TSTORW(I)=DW
      IF(TIMOUT(IO).EQ.IT) 820, 800
  820 CONTINUE
      LM=IGAM + NOGAM*(ITAU-1 + NOTAU*(IO-1))
      IO=IO+1
      IF(IOR.NE.1) GO TO 927
      DO 132 IBM=1,NNUC
      S1A(IBM,LM)=TDOSEA(IBM)
      S1W(IBM,LM)=TDOSEW(IBM)
  132 CONTINUE
  927 CONTINUE
      IF(M.EQ.0) GO TO 11
      DO 430 IXX=1,M
      IP=N9(IXX)
      TDOSEA(IP)=S1A(IP,LM)
      TDOSEW(IP)=S1W(IP,LM)
  430 CONTINUE
   11 CONTINUE
      CALL ORDER(TDOSEA,NAME1,V1)
      CALL ORDER(TDOSEW,NAME2,V2)
      DO 5000 J=1,NNUC,51
      WRITE(51,2500)
      K=MINO(J+50,NNUC)
      WRITE(51,150) GAMOUT(IGAM), TAU, T, ORGNAM(1), ORGNAM(2),
     1 (I,NAME1(I),V1(I),NAME2(I),V2(I),I=J,K)
 5000 CONTINUE
  150 FORMAT(' GAMMA =',F5.1,5X,'TAU =',F8.0,5X,'T =',F8.0,5X,'ORGAN =',
     1 2A8,  /,T30,'SOLUBLE',/,T11,'INHALATION',T45,'INGESTION',/,' NO.'
     2 T7,'NUCLIDE',T18,'REM/MICROCI',T40,'NUCLIDE',T51,'REM/MICROCI',
     3 /,(I4,2X,A8,F15.7,10X,A8,E15.7))
  800 CONTINUE
      IF(IOR.LE.NORG-1) GO TO 72
```

APPENDIX XI, continued

```
      WI=15400.
      AI=1.4*10**8
      DO 740 I=1,NNUC
  740 READ(50,741) MPCWS(I), MPCAS(I)
  741 FORMAT(34X,2E8.0)
      IPD=1
      GO TO 742
  745 DO 744 I=1,NNUC
  744 READ(50,743) MPCWS(I), MPCAS(I)
      IPD=2
  743 FORMAT(50X,2E8.0)
  742 DO 1200 IGAM=1,NOGAM
      IRUN=GAMOUT(IGAM) + .6
      HA=SGAMA(IRUN)/WSMA(4,IRUN)*WSMA(4,21)/SGAMA(21)
      HW=SGAMW(IRUN)/WSMA(4,IRUN)*WSMA(4,21)/SGAMW(21)
      DO 1200 ITAU=1,NOTAU
      TAU=TAUOUT(ITAU)
      DO 1300 I=1,NNUC
      TDOSEA(I)=HA*EXP(-TR(I)*TAU)*.3/(AI*MPCAS(I))
 1300 TDOSEW(I)=HW*EXP(-TR(I)*TAU)*.3/(WI*MPCWS(I))
      CALL ORDER(TDOSEA,NAME1,V1)
      CALL ORDER(TDOSEW,NAME2,V2)
      DO 6000 J=1,NNUC,51
      K=MIN0(J+50,NNUC)
      WRITE(51,2500)
      WRITE(51,176) GAMOUT(IGAM), TAU, (I,NAME1(I),V1(I),NAME2(I),V2(I),
     1 I=J,K)
 6000 CONTINUE
  176 FORMAT(' GAMMA =',F5.1,5X,'TAU =',F8.0,5X,'ORGAN = G.I. TRACT',/,
     1 T29,'INSOLUBLE',/,T11'INHALATION',T45,'INGESTION',/,' NO.',
     2 T7,'NUCLIDE',T18,'REM/MICROCI',T40,'NUCLIDE',T51,'REM/MICROCI',
     3 /,(I4,2X,A8,E15.7,10X,A8,E15.7))
 1200 CONTINUE
      GO TO(745,750),IPD
  750 CONTINUE
      HALF=120.0
      DO 360 I=1,NNUC
      READ(50,202) EPS(I),FA(I),I30
  202 FORMAT(2X,E8.0,8X,E8.0,I4)
      IF(I30.NE.0)HALF=365.0
      TEMP=.693/TR(I)
      TE(I)=HALF*TEMP/(HALF+TEMP)
      HALF=120.0
  360 TL(I)=.693/TE(I)
      RATA=SGAMA(21)/WSMA(6,21)
      SMM=WSMA(6,21)
      DO 1800 IGAM=1,NOGAM
      IRUN=GAMOUT(IGAM) + .6
      DO 1800 ITAU=1,NOTAU
      TAU=TAUOUT(ITAU)
      IO=1
      DO 1400 I=1,NNUC
      TDOSEA(I)=0.0
 1400 TSTORA(I)=0.0
      DO 1800 IT=1,JTIM
      HA=SGAMA(IRUN)/RATA/WSMA(6,IRUN+IT-1)
      T=IT*365.0
      DO 1700 I=1,NNUC
      DA=EXP(-TR(I)*TAU)*51.0*EPS(I)*TE(I)*FA(I)/(SMM*.693)*
     1 (1.0-EXP(-TL(I)*T))
      TDOSEA(I)=TDOSEA(I) + HA*(DA-TSTORA(I))
 1700 TSTORA(I)=DA
```

APPENDIX XI, continued

```
      IF(TIMOUT(IO).EQ.IT) 830, 1600
  830 IO=IO+1
      CALL ORDER(TDOSEA,NAME1,V1)
      DO 8000 J=1,NNUC,51
      WRITE(51,2500)
      K=MINO(J+50,NNUC)
      WRITE(51,234) GAMOUT(IGAM), TAU, T, (I,NAME1(I),V1(I),I=J,K)
 8000 CONTINUE
  234 FORMAT(' GAMMA =',F5.1,5X,'TAU =',F8.0,5X,'T =',F8.0,5X,
     1 'ORGAN = LUNG',/,T11,'INSOLUBLE',/,T11,'INHALATION',/,' NO.',
     2 T7,'NUCLIDE',T18,'REM/MICROCI',/,(I4,2X,A8,E15.7))
 1600 CONTINUE
 1800 CONTINUE
      END
```

APPENDIX XI, continued

```
      SUBROUTINE ORDER(ARR,NA,VA)
      COMMON NAME, NNUC
      DIMENSION ARR(112), VA(112)
      DOUBLE PRECISION NAME(192), NA(192), I1
      DO 10 I=1,NNUC
      NA(I)=NAME(I)
   10 VA(I)=ARR(I)
      IUP=NNUC
    3 IC=0
      IUP=IUP-1
      DO 1 I=1,IUP
      IF(VA(I).GE.VA(I+1)) GO TO 1
    2 T=VA(I)
      I1=NA(I)
      VA(I)=VA(I+1)
      NA(I)=NA(I+1)
      VA(I+1)=T
      NA(I+1)=I1
      IC=1
    1 CONTINUE
      IF(IC.EQ.1) GO TO 3
    4 RETURN
      END
```

APPENDIX XI, continued

Program SAN — normalizes and lists, in descending order, the radiosensitivity-adjusted internal doses used to prepare the composite radionuclide dose commitment lists found in Appendix X.

```
**FTN,L,E,G.
      PROGRAM SAN
      DOUBLE PRECISION NAME1(112), NAME2(112), NAME3(112), NAME4(112)
      DIMENSION V1(112), V2(112), V3(112), V4(112), HEAD(160)
   60 DO 10 N=1,4
      J=30*(N-1)+1
      K=J+30
   10 READ(50,100) (HEAD(I),I=J,K)
  100 FORMAT(20A4)
      NIO=101
  102 FORMAT(30A4)
C*** ORDER OF INPUT
C   1.SOLUBLE - INGESTION
C   2.SOLUBLE - INHALATION
C   3.INSOLUBLE - INGESTION
C   4.INSOLUBLE - INHALATION
      DO 20 I=1,NIO,3
      K=I+2
   20 READ(50,103)(NAME1(J),V1(J),J=I,K)
      DO 30 I=1,NIO,3
      K=I+2
   30 READ(50,103)(NAME2(J),V2(J),J=I,K)
      DO 40 I=1,NIO,3
      K=I+2
   40 READ(50,103)(NAME3(J),V3(J),J=I,K)
      DO 50 I=1,NIO,3
      K=I+2
   50 READ(50,103)(NAME4(J),V4(J),J=I,K)
  103 FORMAT(A8,E12.0,A8,E12.0,A8,E12.0)
      CALL ORDER(NAME1,V1)
      CALL ORDER(NAME2,V2)
      CALL ORDER(NAME3,V3)
      CALL ORDER(NAME4,V4)
  104 FORMAT(I4,2X,A8,E13.3,7X,A8,E13.3,7X,A8,E13.3,7X,A8,E13.3)
      DO 80 J=1,NIO,51
      K=MINO(J+50,NIO)
      WRITE(51,101)
      WRITE(51,102) (HEAD(I),I=1,120)
      WRITE(51,104) (I,NAME1(I),V1(I),NAME2(I),V2(I),NAME3(I),V3(I),
     1 NAME4(I),V4(I),I=J,K)
   80 CONTINUE
  101 FORMAT('1',T5,'COMPOSITE LISTINGS OF RADIONUCLIDES BASED ON DOSES
     1TO THE CRITICAL ORGANS FROM 1 MICROCURIE INTAKES')
      GO TO 60
      END
```

APPENDIX XI, continued

```
      SUBROUTINE ORDER(NAME,V)
      DOUBLE PRECISION NAME (112), I1
      DIMENSION V(112)
      NIO=101
    3 IC=0
      NIO=NIO-1
      DO 1 I=1,NIO
      IF(V(I).GE.V(I+1)) GO TO 1
      T=V(I)
      I1=NAME(I)
      V(I)=V(I+1)
      NAME(I)=NAME(I+1)
      V(I+1)=T
      NAME(I+1)=I1
      IC=1
    1 CONTINUE
      IF(IC.EQ.1) GO TO 3
      T=V(1)
      DO 10 I=1,101
   10 V(I)=V(I)/T
      RETURN
      END
```

ORNL-4101
UC-48 — Biology and Medicine

INTERNAL DISTRIBUTION

1. Biology Library
2-4. Central Research Library
5-6. ORNL — Y-12 Technical Library Document Reference Section
7-41. Laboratory Records Department
42. Laboratory Records, ORNL R.C.
43-142. S. I. Auerbach
143. S. J. Ball
144. B. G. Blaylock
145. R. L. Bradshaw
146. P. E. Brown
147. T. J. Burnett
148. J. S. Cheka
149. R. L. Clark
150-174. K. E. Cowser
175. D. A. Crossley, Jr.
176. J. W. Curlin
177. D. M. Davis
178. W. Davis, Jr.
179. P. B. Dunaway
180. B. R. Fish
181. M. R. Ford
182. G. S. Hurst
183. D. R. Johnson
184. W. H. Jordan
185. M. A. Kastenbaum
186-210. S. V. Kaye
211. T. F. Lomenick
212. C. E. Larson
213. H. G. MacPherson
214. K. Z. Morgan
215. D. J. Nelson
216. J. S. Olson
217. L. F. Parsly
218-227. P. S. Rohwer
228. M. J. Skinner
229. W. S. Snyder
230-254. E. G. Struxness
255. R. L. Tabor
256. F. G. Taylor, Jr.
257. D. K. Trubey
258. V. R. Rao Uppuluri
259. A. D. Warden
260. A. M. Weinberg
261. J. P. Witherspoon
262. M. Witkamp
263. R. G. Wymer
264. J. E. Cantlon (consultant)
265. J. C. Frye (consultant)
266. J. B. Hursh (consultant)
267. J. L. Magee (consultant)
268. H. O. Wyckoff (consultant)

EXTERNAL DISTRIBUTION

269-468. W. J. Martin, Battelle Memorial Institute, Columbus, Ohio
469-472. A. W. Klemment, USAEC Nevada Operations Office, Las Vegas, Nevada
473-474. J. E. Reeves, USAEC Nevada Operations Office, Las Vegas, Nevada
475. C. S. Shoup, USAEC Oak Ridge Operations Office, Oak Ridge, Tenn.
476. H. M. Roth, USAEC Oak Ridge Operations Office, Oak Ridge, Tenn.
477. J. N. Wolfe, USAEC Headquarters, Washington, D.C.
478. R. Hamburger, USAEC Headquarters, Washington, D.C.
479. J. J. Davis, USAEC Headquarters, Washington, D.C.
480. J. Z. Holland, USAEC Headquarters, Washington, D.C.
481. F. E. Western, USAEC Headquarters, Washington, D.C.
482. B. W. Shore, Lawrence Radiation Laboratory, Livermore, California
483. A. R. Tamplin, Lawrence Radiation Laboratory, Livermore, California
484. Y. C. Ng, Lawrence Radiation Laboratory, Livermore, California
485. Executive Director, Federal Radiation Council, Washington, D.C.
486. J. R. Kline, Caparra Heights Station, Puerto Rico Nuclear Center, San Juan, Puerto Rico
487. V. Schultz, Department of Zoology, Washington State University, Pullman, Washington

488. G. Van Dyne, Colorado State University, Fort Collins, Colorado
489. R. J. Anderson, Assistant Surgeon General, Chief, Bureau of State Services, USPHS, Department of Health, Education and Welfare, Washington, D.C.
490. G. A. Andrews, Medical Division, Oak Ridge Associated Universities, Oak Ridge, Tennessee
491. M. J. Berger, Division 231.01, National Bureau of Standards, Washington, D.C.
492. D. R. Chadwick, Division Radiological Health, USPHS, Room 5094, South Building HEW, Washington, D.C.
493. Walter Belter, Division of Reactor Development, USAEC, Washington, D.C.
494. W. W. Grigorieff, Assistant to the Executive Director, Oak Ridge Associated Universities, Oak Ridge, Tennessee
495. J. R. Horan, P.O. Box 2108, Idaho Falls, Idaho
496. H. A. Kornberg, Biology Department, Battelle Northwest, P.O. Box 999, Richland, Washington
497. W. J. Lacy, Office of Civil Defense, Pentagon, Washington, D.C.
498. J. A. Lieberman, Division of Reactor Development, USAEC, Washington, D.C.
499. S. A. Lough, Division of Biology and Medicine, USAEC, Washington, D.C.
500. L. D. Marinelli, Argonne National Laboratory, 9700 Cass Avenue, Argonne, Illinois
501. F. L. Pascal, Jr., General Dynamics, Ft. Worth, Plant Zone Y-42, P.O. Box 748, Fort Worth, Texas
502. C. M. Patterson, E. I. duPont de Nemours, Savannah River Laboratory, Aiken, South Carolina
503. W. C. Roesch, Battelle Northwest, P.O. Box 999, Richland, Washington
504. C. E. Roos, Department of Physics, Vanderbilt University, Nashville, Tennessee
505. R. L. Shearin, Environmental Radiological Health Training, R. A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati, Ohio
506. J. N. Stannard, University of Rochester School of Medicine and Dentistry, Department of Radiation Biology and Atomic Energy Project, P.O. Box 287, Station 3, Rochester 20, New York
507. C. P. Straub, University of Minnesota, College of Medical Sciences, School of Public Health, Minneapolis, Minnesota
508. J. A. Swartout, 270 Park Avenue, New York 17, New York

509-776. Given distribution as shown in TID-4500 under Biology and Medicine category (25 copies — CFSTI)